JOURNAL

JOURNAL

OF THE INSTITUTION OF ELECTRICAL ENGINEERS

SAVOY PLACE LONDON W.C.2

TELEPHONE: TEMPLE BAR 7676 TELEGRAMS: VOLTAMPERE PHONE LONDON

VOLUME 2 (NEW SERIES) NUMBER FOURTEEN FEBRUARY 1956

PUBLISHED MONTHLY PRICE FIVE SHILLINGS

ANNUAL SUBSCRIPTION TWENTY-FIVE SHILLINGS

Contents

PAGE 83 THE INSTITUTION AND RADIO INTERFERENCE

84 THE PREVENTION OF THE CORROSION OF FERROUS METALS
by J. C. HUDSON, D.SC., F.I.M.

89 THE PRINCIPLES OF N.T.S.C. COLOR TELEVISION
by CHARLES J. HIRSCH, MEMBER

98 EDUCATION AND TRAINING OF RUSSIAN TECHNOLOGISTS
by WILLIS JACKSON, VICE-PRESIDENT

102 THE START OF THE BRITISH NUCLEAR ENERGY CONFERENCE

104 HOME EVENTS

110 CORRESPONDENCE

111 A REVIEW OF THE *PROCEEDINGS*, PARTS A AND B

119 OBITUARY

120 MONOGRAPHS AND PAPERS PUBLISHED SEPARATELY THIS MONTH

122 ANNOUNCEMENTS TO MEMBERS

125 FORTHCOMING EVENTS AT SAVOY PLACE

125 DISTRICT MEETINGS

126 BRITISH NUCLEAR ENERGY CONFERENCE

126 CONTENTS OF THE CURRENT ISSUES OF THE *PROCEEDINGS*

The Institution is not, as a body, responsible for the opinions which are expressed in the *Journal*, unless it is stated that an article, letter or announcement officially represents the Council's views.

JOURNAL

OF THE INSTITUTION OF ELECTRICAL ENGINEERS

VOLUME 2 (NEW SERIES) NUMBER 14 FEBRUARY 1956

THE INSTITUTION AND RADIO INTERFERENCE

THE INSTITUTION HAS LONG REALIZED THE importance of reducing the interference which electrical apparatus and plant cause to radio-communication in general and to broadcasting in particular. Indeed in 1933 the Council appointed a small "preparatory committee" to review the subject; and later in the same year it set up the Radio Interference Committee under the chairmanship of Dr. Clifford Paterson, who provided invaluable leadership until his death in 1948. Regulations controlling interference with the older sound broadcasting and television services have only recently come into force. Moreover, new broadcasting and television services on higher frequencies are being introduced. It may therefore be useful to review the work and responsibilities of The Institution in helping to reduce radio interference in this country.

From 1933 to 1949 The Institution acted primarily as an unofficial but authoritative adviser to the various bodies tackling the problem. It provided a forum where all interested could express their views: not only those who would benefit from an improvement in receiving conditions, but those who might be asked to make a sacrifice to allow such improvement. At an early stage the Radio Interference Committee asked the British Standards Institution to prepare standard specifications for the components required for suppression of interference and instruments suitable for measuring it objectively. From this small beginning has grown the present range of British Standards and Codes of Practice on interference, of which perhaps the most important are B.S. 613, "Components and Filter Units for Radio Interference Suppression"; B.S. 727, "Apparatus for Measurement of Radio Interference"; B.S. 800, "Limits of Radio Interference"; and C.P. 1006, "General Aspects of Radio Interference Suppression," which is in effect a useful introductory textbook. The Codes of Practice have been produced by drafting committees jointly appointed by The Institution and the B.S.I.: they are now in the province of the Codes of Practice Council, which operates in the framework of the B.S.I. with the status of a Divisional Council.

Without doubt the most important recommendation in the 1936 report of the Radio Interference Committee was that "compulsory powers should be conferred on some authority" to require interference suppression where appropriate. At about the same time the report of the Ullswater Committee on Broadcasting suggested that if the Postmaster General needed further powers to protect listeners from interference, the Government should seek them. The war intervened, and the necessary powers were eventually obtained under Part 2 of the Wireless Telegraphy Act, 1949. This Act enables the Postmaster General to make regulations controlling radio interference after consulting an advisory committee whose members are appointed from a panel nominated by the President of The Institution with the approval of the Council. Using these powers, the Postmaster General has issued regulations applying to the ignition systems of internal-combustion engines, to refrigerators, and to small electric motors. The Act also provides for an appeal tribunal, consisting of a lawyer as chairman and two assessors appointed by the President of The Institution. The Institution clearly has great responsibility in these matters, because the wisdom of its nominees will largely determine the effectiveness of interference regulations.

The British Standards and Codes of Practice so far issued do not cover the two most recent developments in broadcasting, namely frequency-modulated sound broadcasting in Band II and television in Band III. However, the Radio Interference Committee, now under the chairmanship of Sir Stanley Angwin, have already stimulated exploratory work on the measurement and suppression of radio interference on these higher frequencies, and as the new services develop data will be obtained which can be placed before the various drafting committees.

The Institution therefore has much further work to do: it may be necessary to extend the scope of existing regulations to cover the higher frequencies, and in any event the country will in due course need new regulations for other apparatus. New electrical products which may themselves constitute new sources of interference, and new radio services, particularly those at higher frequencies, may make fresh demands on the techniques of interference measurement and suppression. The Institution's services will thus be required in the future, perhaps even more than in the past, to secure harmony between the radiocommunication and power interests of the electrical engineering industry for the benefit of society.

The Prevention of the Corrosion of Ferrous Metals

J. C. Hudson, D.Sc., F.I.M.

The British Iron and Steel Research Association has carried out valuable work on the problem of corrosion. However, the Corrosion Committee of the Association feels that the practical conclusions to be drawn from its work are not as widely known or as fully applied as is desirable in the public interest; to bring them to the attention of electrical engineers, Dr. Hudson, who is the Head of the Corrosion Laboratory, B.I.S.R.A., describes here the mechanism of corrosion of iron and steel, and outlines various methods of protection against it.

Introduction

THE corrosion of metals is a source of serious financial loss and a great deal of inconvenience, much of which could be avoided if the appropriate preventive measures were taken. The problem is particularly important for iron and steel, both because of the preponderating part played by ferrous metals as materials of construction and because they are more vulnerable to corrosion than most other metals commonly used in industry, such as aluminium, copper, nickel and zinc. It is not surprising, therefore, that systematic research on the corrosion of iron and steel and its prevention should have been in progress in several countries for many years.

In Great Britain a Corrosion Committee, which now forms part of the British Iron and Steel Research Association, has been at work since 1929. Tests have been made on specimens of numerous types of iron and steel exposed to corrosion by air, soil or water, both in the bare condition and when protected in various ways, notably by paints and metallic coatings.

The methods used for preventing rusting may be classified as follows:

(i) Alterations in the corrosive medium.
(ii) Alterations in design.
(iii) Alterations in the composition of the iron or steel.
(iv) Application of protective coatings.
(v) Cathodic protection.

Alterations in the Corrosive Medium

The rusting of iron is the outcome of the natural tendency of the metal to revert to the ore from which it was derived, and is always liable to occur when iron is in contact with oxygen and moisture, but the attack is not severe unless both are present simultaneously. It has been found, for example, that iron does not rust appreciably in atmospheres of low relative humidities, say below 70%. Consequently, under special circumstances, the atmospheric corrosion of iron and steel can be prevented or reduced by drying the air. Although, for obvious reasons, this treatment is only practicable on a limited scale, it is used with success in industries such as the needle industry, where certain rooms are air-conditioned in order to prevent the tarnishing of bright steel parts before they can be securely packed.

Alterations in the corrosive medium are most effective where ferrous metals are exposed to attack by fresh waters; in fact one of the main functions of water treatment is to prevent attack by the water on the supply pipes through which it is fed. The ideal is to produce a water of such hardness and other properties that a slight initial corrosion of the pipes produces an insoluble surface film of rust and other solids derived from the water, which shields the pipe against further attack; the addition of small amounts of suitable inhibitors such as sodium silicate, often helps towards attaining this end.

The provision of surrounds of calcareous sand for pipes buried in corrosive soils may be regarded as falling in this category.

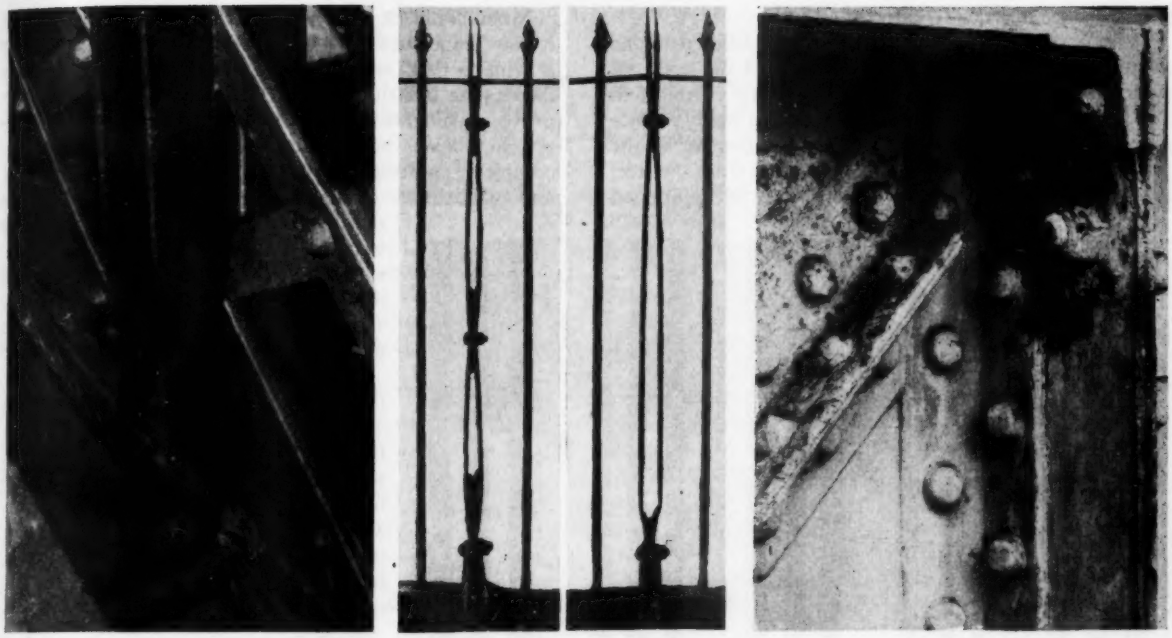
Alterations in Design

Details of design can have a decisive influence on corrosion. Every effort should be made to facilitate the drainage of rain or dew from a fabricated structure and to avoid ledges, nooks and crannies, where water, dust and rust can accumulate, sometimes with disastrous results. A few typical examples in which corrosion has been aggravated through design are shown in Fig. 1.

Another vital feature that is often overlooked is the necessity of providing adequate facilities for the renewal of protective coatings when necessary. It is bad practice to design a structure with "back to back" angles or other parts that the painter cannot reach with his brush. As an example of this, several tons of rolled steel joists supporting the floor of a cold store had to be replaced, merely because they had been twinned and set so closely together that their inner surfaces were inaccessible for painting. Over a period of years these surfaces became so heavily rusted through the heavy condensation of moisture caused by the cold above that the safety of the building was imperilled.

Alterations in the Composition of the Iron or Steel

Steel can be rendered almost immune to attack by many corrosive agencies through the addition of alloying elements. For example, in tests by H. T. Shirley and J. E. Truman, a polished rust-resisting steel containing 18% of chromium, 8% of nickel and 2·5% of molybdenum, remained practically unattacked by 5 years'



a b c

1 *Effect of design on corrosion*

(*a*) Detail of non-structural member (balustrade) of footbridge at St. James's Park, London. This type of lattice construction, including upturned back-to-back angles at the bottom, offers dangerous opportunities for the accumulation of dust and moisture, which is followed by serious corrosion. (Photograph by courtesy of the Ministry of Works.)
(*b*) Railings near Clapham Junction; the weakness of this design is obvious.
(*c*) Detail of a panel of the toll bridge at Caernarvon. A recessed riveted assembly such as this is very difficult to paint effectively.

exposure to the Sheffield atmosphere and, after the grime had been removed from it, was found to have retained most of its original polish. The loss in weight of this steel on exposure was negligible, being roughly 3000 times less than that of an ordinary mild structural steel exposed beside it.

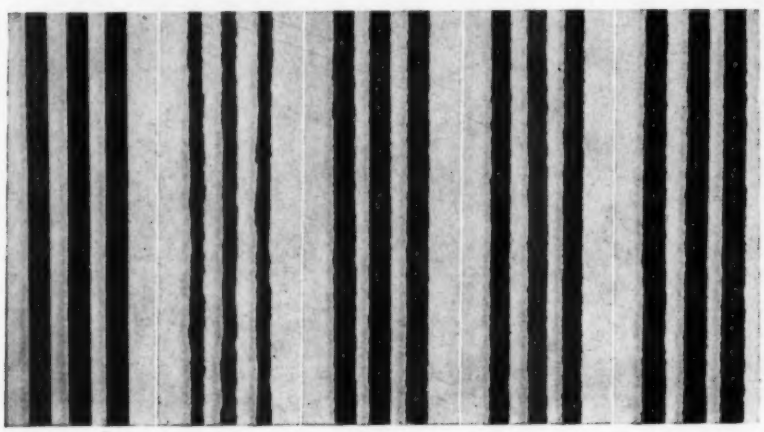
Unfortunately, the use of rust-resisting steels such as this is limited by the relative scarcity and high cost of the necessary alloying materials. Consequently, although steels of this type are capable of providing a satisfactory solution for many corrosion problems, there can be no question of their general use for the common run of structural work. Their main applications in industry will be for special uses where corrosion resistance is of supreme importance. An example of this in the electrical industry is the use of rust-resisting steels for certain parts of fluorescent street-lighting equipment that are fully exposed to the weather.

In contrast to this, another group of steels, the "low-alloy" steels, offers a practicable solution of the corrosion problem for many industrial purposes. These steels, which contain small percentages of chromium, copper or nickel, are not completely rust-resistant but they rust more slowly than ordinary mild steel, because a more compact and less permeable layer of rust gradually develops on them, as shown in Fig. 2. One of the best-known industrial steels of this type, originally developed in the United States, contains about 1% of chromium, 0·6% of copper and has rather higher phosphorus and silicon contents than ordinary steel. Although the main reason for the introduction of this and similar steels was their enhanced mechanical properties—some of them have a tensile strength of 40 tons/in.^{2} or more, as compared with about 28 tons/in.^{2} for unalloyed mild steel—tests have shown that their resistance to corrosion in the open atmosphere is several times that of ordinary steel. For example, over a period of 5 years' exposure, during which the protective rust layer had time to develop on it, the loss in weight of a low-alloy steel with the composition mentioned was found to be only 23% of the average loss of four ordinary steels exposed beside it.

These slow-rusting low-alloy steels are naturally more expensive than ordinary steel but the differences in price are sufficiently low to render their use economical for many purposes. This is particularly advantageous for thin sections, structures exposed to industrial or marine atmospheres, or structures on which maintenance painting is difficult. It should be noted, however, that the presence of low-alloy elements in steel has no marked effect on its corrosion resistance when it is submerged in water, buried in soil, or exposed in enclosed atmospheres, such as railway tunnels.

Protective Coatings

Paint. Considerable research has been devoted to the protective painting of structural steel and the essential principles for success have now been firmly established. By far the most important factor is proper surface preparation. The correct procedure is to remove all the mill-scale and any rust that may be present from the steel before it is painted, so that the priming coat is applied to a perfectly clean, metallic surface. Methods of cleaning steel depend on the type of structure to be protected.



2 *Effect of small additions of chromium, copper and nickel on the resistance of structural steel to atmospheric corrosion*

Low-alloy mild-steel wires ¼ in. diameter exposed outdoors at Sheffield for 5 years compared with unexposed wire.
(*a*) Unexposed wire. (*c*) Chromium, 2·0%. (*e*) Nickel, 3·1%.
(*b*) No alloy addition. (*d*) Copper, 0·5%.

For light-gauge steel, as used, for example, in the automobile industry, phosphating processes are useful. In these processes the steel is treated with hot solutions of phosphates of iron, zinc or manganese, in phosphoric acid and a film of phosphate is formed on the surface. For heavy structural steel, pickling and grit-blasting are the most effective and economical methods of obtaining the perfect metallic surface that is required to ensure success. For use on existing structures flame-cleaning, which consists in passing an intense oxy-acetylene flame over the surface, has certain advantages. This is particularly the case where an old structure has been allowed to rust appreciably through lack of maintenance at the proper time. On the whole, however, where practicable, the duplex method of pickling, developed by H. B. Footner, would seem to be as good as any. In this process the mill-scale is first removed from the steel by pickling in hot dilute sulphuric acid; the steel is then rinsed with hot water and is finally immersed for a few minutes in a hot dilute solution of phosphoric acid. The priming coat of paint is applied to the steel in the shop whilst it is still warm, as soon as it has dried off under its own heat capacity after removal from the last bath.

Much could be written about the choice of paints but it must suffice to state here that for all-round use on steel a priming paint of mixed red and white leads in accordance with British Standard 2523 : 1954, Type C, should prove as suitable as any. It is vital that the individual priming coats, undercoats and finishing coats of the complete painting scheme should be intercompatible and of adequate thickness; it is unwise to provide less than 5 mils cover for important steel structures, unless they happen to be exposed to exceptionally mild conditions. This thickness of paint corresponds to at least three or, more generally, four coats of paint.

Properly painted structures should not need further attention under normal circumstances for an appreciable time. In experimental work, two-coat painting schemes have protected steel completely for about 7 years in a highly corrosive atmosphere at Derby, and performances of the same order should be obtainable from the much thicker coatings recommended above for use on actual structures.

Metal Coatings, notably of zinc and aluminium, are an effective means of protecting iron and steel from corrosion and they are being used to an increasing extent for this purpose on steel structures.

Zinc can be applied by several processes: sherardizing, hot-dipping, electro-deposition and spraying. Fig. 3 shows that the durability of protection achieved is mainly determined by the coating weight and is independent of the process of application used. There is an upper limit of about 0·8 oz/ft² for sherardized coatings, and the weight of zinc deposited by hot-dipping cannot be increased much above 2 to 3 oz/ft², particularly for thin sections. The latter limit corresponds, however, to roughly 3–5 mils thickness, and for most practical purposes there would be little point in exceeding this.

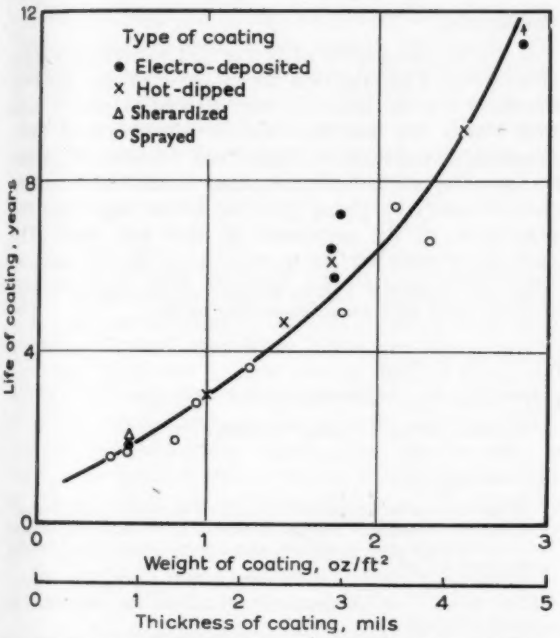
Metal spraying is the only practicable means of applying aluminium to steel plates and sections, although hot-dipping processes are in operation for coating thin steel sheet or strip in coil with an aluminium-silicon alloy. Within the last few years considerable advances have been made in metal-spraying techniques, notably by mechanizing the spraying plant. These developments have tended to reduce costs in appropriate circumstances and have thus stimulated the industrial use of sprayed metal coatings of both aluminium and zinc for heavy structural steel.

The successful use of metal coatings for the protection of steel structures is illustrated by the following two examples.

Zinc coatings have been extensively used by the

Central Electricity Authority and its predecessors for their steel transmission towers. These towers were hot-galvanized in small pieces and received a coating of zinc weighing about 2 oz/ft², or about 3 mils thick. They were erected without painting and the Authority has since observed that painting first became necessary after up to 10 years in industrial areas, up to 12 years near the coast, and up to 20 years in the country. These may be regarded as long and satisfactory lives.

Aluminium spraying has recently been employed to protect certain buildings at the various works of a large steel company. At one place all the steel above the level of a crane runway, amounting to 15000 tons, was shot-blasted, sprayed with aluminium to a thickness of 4 mils



3 *Effect of coating weight on the durability of zinc coatings on steel exposed outdoors at Sheffield*

and then given a single coat of paint. This treatment was estimated to cost roughly twice as much as the application of a complete painting scheme to weathered and wire-brushed steel, which was the method adopted for the protection of the rest of the steelwork, but it is anticipated that the additional first cost for the aluminium-coated steel will be more than recouped by appreciable reductions in the subsequent cost of maintenance.

It should be emphasized that, although zinc and aluminium are considerably more resistant to atmospheric corrosion than steel, coatings of these metals will themselves be corroded away in time and will, therefore, need painting. It may be preferable to do this painting before erection, particularly so perhaps when the painting at the site will have to be done in a highly corrosive atmosphere. The question of the most suitable paints for application over metallic coatings on steel has not yet been fully answered and the subject is being studied by the Protective Coatings (Corrosion) Sub-Committee of the British Iron and Steel Research Association.

Bitumen and coal-tar pitch are especially useful for the protection of buried or submerged pipes.

Concrete made from carefully selected ingredients, thoroughly consolidated, may be used to protect embedded steel and at least 2 in. of cover at all points should be provided.

Wrapping tape, consisting of a plastic wrapper loaded with a protective grease, is particularly useful for the protection of pipes, etc., exposed to highly corrosive atmospheric conditions.

Vitreous enamel is one of the best coatings for withstanding the combination of heat and a corrosive atmosphere, but it is, unfortunately, difficult to apply to heavy parts and is vulnerable to mechanical damage.

Lanoline preparations and sulphonated petroleum derivatives are often used for the temporary protection of steel.

*Cathodic Protection**

The principles underlying cathodic protection have been known for more than a century but it is only within recent years that the method has been used on a substantial scale, particularly in Great Britain. Cathodic protection depends on the fact that, where an electrolyte is present corrosion is electrochemical in character, i.e. one part of the structure (the *anode*) assumes a less noble potential than another (the *cathode*), so forming an electrolytic cell. The anodic area is corroded while the cathodic area is not. The anode and the cathode may be formed by two different metals in contact with each other, or they may arise at different points on the surface of the same metal. Cathodic protection is based on the provision of an artificial electric circuit in which the metal to be protected is made the cathode of the corrosion cell.

In practice cathodic protection is applied to buried or submerged iron or steel by coupling the structure to auxiliary electrodes, called *sacrificial anodes*, buried or submerged alongside it. These electrodes can either be of some metal less noble than iron—magnesium is commonly used—so that the assembly generates the necessary electric current itself, or of some inert material such as scrap steel or graphite, when it is necessary to pass an electric current from an outside source through the circuit in the appropriate direction. Obviously the method can be effective only if the corrosive medium surrounding the steel is a good conductor of electricity.

* A more specialized article on cathodic protection appeared in the January issue, page 2.

For this reason, cathodic protection is most suitable for buried steel, or for steel immersed in sea-water; it cannot be applied to atmospheric structures. Moreover, although the method is simple in principle, its practical application to a specific case is best entrusted to experts with specialized knowledge in this field.

Corrosion by Soil

Corrosion by soil under practical conditions is complicated by several factors, such as long-line currents, which cannot be adequately studied by small-scale experiments. The results of tests on short lengths of buried iron or steel pipe may not, therefore, be fully indicative of the behaviour of a long pipeline. With this reservation, the results of such experiments show that in general the corrosive effects of most soils are not excessive, and that, even in the worst cases, the rates of average general penetration are about the same as those observed when iron or steel is exposed to highly polluted industrial atmospheres.

As, however, most buried pipes are used to carry commodities, such as gas, oil or water, the incidence of pitting is of extreme importance in soil corrosion. In this respect the corrosive attack can be aggravated in two ways. The first is connected with the existence in soils of certain bacteria that render corrosion possible in the absence of atmospheric oxygen. In permeable soils the necessary oxygen is derived directly by diffusion from the atmosphere or is available in solution in the soil water. Oxygen is lacking, however, in impervious soils such as waterlogged clays, and the corrosion of iron in these soils would be reduced to a negligible level were it not for the action of these bacteria. As it is, the bacteria make available the oxygen needed for the corrosion process by their action on sulphates, notably calcium sulphate, present in the soils, which they reduce to sulphides in the course of their metabolism. The resulting corrosion is severe and often localized, so that some of the worst corrosion is observed in oxygen-free clay soils.

The second factor conducive to local penetration applies to cast iron. This material is liable to suffer a form of attack known as graphitization, in which the iron matrix of the pipe is destroyed, leaving a weak and brittle skeleton consisting mainly of graphite. Graphitization is particularly liable to occur where sulphate-reducing bacteria are present.

The corrosive effects of clays and other aggressive soils can be considerably alleviated, where this step is economical, by providing the buried iron or steel with a permeable surround, not less than 9 in. thick, of sand gravel or chalk. This ensures good drainage and promotes conditions of good oxygen supply in which the sulphate-reducing bacteria cannot thrive. It should be emphasized, however, that in these and all types of soil, the provision of an adequate and sound protective coating must be the essential and first line of defence. For this purpose, heavy coatings of coal-tar pitch or blown bitumen have proved their worth and are in general use. Under the worst conditions a thickness of $\frac{3}{8}$ in. of pitch or bitumen, suitably reinforced with a glass wool or other inert wrapping, is not too much. Thick concrete coatings, giving at least 3 in. of cover, are also effective; where high concentrations of sulphates are present in the soil, aluminous cement should be used rather than Portland cement.

Cathodic protection is a valuable means of protecting buried iron and steel but it should always be regarded as a supplement to, and not as a substitute for, an effective protective coating. This is because, even if it were practicable to protect an uncoated structure by cathodic protection alone, the cost of doing so would be prohibitive.

Bibliography

A short bibliography of books and papers providing more detailed information about some of the subjects discussed is given below. It may also be helpful to add that within the last year the British Iron and Steel Research Association, 11 Park Lane, London, W.1, has set up a Corrosion Advice Bureau, whose function is to assist industry by giving practical advice regarding the prevention of the corrosion of iron and steel. The Bureau's services are free to members of the Association but, in appropriate cases, inquiries from non-members may be dealt with on a fee-paying basis.

General and Theoretical

EVANS, U. R.: "An Introduction to Metallic Corrosion" (Arnold, 1948).

"The Prevention of Corrosion" (B.I.S.R.A., 1954).

Corrosion in Air

"Symposium on the Protection of Structural Steel against Corrosion," shortly to be published in a single volume by the Society of Chemical Industry. The individual papers have appeared in *Chemistry and Industry* or the *Journal of Applied Chemistry*.

"The Painting Manual." Vol. 1, "Good Painting Practice," 1954; Vol. 2, "Systems and Specifications," 1955. (Steel Structures Painting Council, Pittsburgh.)

FANCUTT, F., and HUDSON, J. C.: "Protective Painting of Structural Steel" (Chapman and Hall, 1956).

Corrosion in Soil

"Symposium on the Corrosion of Buried Metals" Special Report No. 45 (The Iron and Steel Institute, 1952).

SPENCER, K. A., and FOOTNER, H. B.: "Protective Coatings for Buried Pipelines," *Chemistry and Industry*, 1953, No. 19, p. 448.

Cathodic Protection

"Symposium on Cathodic Protection" (Society of Chemical Industry, 1953).

In common with many other periodicals, this issue of the *Journal* has been reduced in size owing to the dispute in the printing industry. As a result it has been necessary to hold over certain regular items.

The Principles of N.T.S.C. Color* Television

CHARLES J. HIRSCH, MEMBER

As is widely known, the United States Federal Communications Commission decided in December, 1953, to standardize broadcast color television in America on the compatible N.T.S.C. system. This was done only after years of controversy and detailed examination of the merits of rival systems, compatible and non-compatible, which included a period of approval for the abortive C.B.S. system. The adoption of the N.T.S.C. system has given a fillip to research into similar systems for use in other countries; recently the B.B.C. have been actively engaged in trials of a modification of the N.T.S.C. system to suit British television standards, though the Corporation have stressed that the start of a regular color-television service in Britain is not imminent, and that they are not in fact committed to any particular system or even to compatibility; decisions on these matters will be made by the Postmaster General, acting on the advice of the Television Advisory Committee.

The author of this expository article, Mr. Hirsch, has, as Chairman of the United States Delegation to Study Group XI (Television) of the C.C.I.R., played a prominent role in international deliberations on color television, and his present work for the Hazeltine Corporation, New York, includes research into its current problems. He is well known to many members of the Radio and Telecommunication Section as he gave an informal talk—on the same lines as this article—to the Section about the N.T.S.C. system as long ago as March, 1954.

THIS article treats of the method of color television which was developed by the National Television System Committee (N.T.S.C.) and is now being broadcast in the United States. The system is compatible, i.e. color television pictures can be seen, in black and white, on existing black-and-white (monochrome) receivers without any alterations to the receivers. Conversely black-and-white transmissions can be seen, in black and white, on color receivers. Briefly, the principle of this system is that color is added to black-and-white pictures in a manner similar to coloring a monochrome photograph by means of colored crayons or paints.

The N.T.S.C. color television system is described in this article within the framework of the 525-line system used in the United States. However, these principles apply equally well to the 405-line system used in the United Kingdom, the 819-line system used in France, and the 625-line system used elsewhere in Europe. Operation of the N.T.S.C. principles on these other systems requires adapting bandwidths, frequency of the color sub-carrier, etc., to the characteristics of these systems. The British 405-line system has more effective horizontal bandwidth than the U.S. 525-line system. It can, therefore, support more easily the addition of a coloring signal and should be more compatible than the U.S. 525-line system. Investigation of these principles is already far advanced in the United Kingdom, and experimental color television transmissions are taking place.

* In a preamble to this article Mr. Hirsch said:
"The 'color' about which I am talking is spelt without a 'u.' It is up to you in Britain to add the 'u,' but how you do it is your own problem. I have a suspicion that you are going to pay the penalty of having been pioneers and that the adaptation of color may be slightly more difficult than it has been in the United States. You may have to add a few extra valves to put the 'u' in 'colour.' I shall write only of 'color' without a 'u.'"
At the risk of upsetting orthographically minded readers we willingly accept the slight excuse to adopt temporarily the American spelling of the word "colour". However, British terminology is followed in the use of *picture* and *frame* rather than *frame* and *field*, respectively.—*Editor.*

General Considerations

Three independent quantities are required to specify a color fully. These may be luminance,* dominant wavelength,* and purity,* which correspond respectively to the psycho-physical sensations of brightness,* hue,* and saturation.* Another set may be the intensities of three primaries, red, green, and blue. The specification in one set may be mathematically transformed into the other set. Present-day cameras and displays can operate only in terms of primaries. This appears to imply that the transmission of color by television requires three high-definition pictures, one for each primary. However, the eye can detect small details of brightness but details in chromaticity (hue plus saturation*) are much less easily resolved. This suggests that color pictures should be produced by the transmission of a full-resolution luminance picture to which the minimal (in bandwidth) amount of coloring information is added. This process results in producing color pictures with a total bandwidth only 25–30% greater than for monochrome pictures. While the camera produces (and the display responds to) voltages related to the intensity of the primaries, the transmitter transforms these into voltages which are related to luminance and chromaticity for economy of bandwidth in transmission. The receiver performs the opposite transformation.

N.T.S.C. color television transmits the luminance pictures by the standards now in force for monochrome television. Thus existing and unaltered black-and-white receivers can receive the color transmission, i.e. they are compatible.

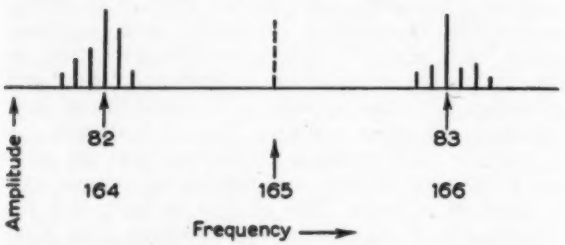
The coloring information, i.e. the difference between the color and the black-and-white pictures (called

* For definitions of these and other terms see B.S. 1611: 1953, "Glossary of Colour Terms used in Science and Industry."

*chrominance**), is transmitted by a suppressed sub-carrier which is modulated by a video signal related to *chromaticity multiplied by luminance*. This ensures that the added sub-carrier's sidebands disappear in the black areas where the luminance is zero. In addition the chrominance sub-carrier is so encoded that its amplitude is proportional to purity of color and therefore disappears in colorless areas of the picture. In those areas the complete color signal is identical to standard monochrome transmissions.

Band-Sharing by Luminance and Chrominance Signals

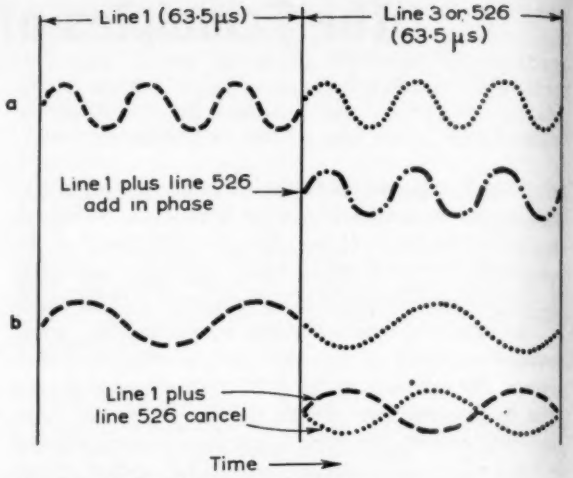
The chrominance sub-carrier and its sidebands share the same bandwidth as a standard monochrome signal. This is possible because the television spectrum consists essentially of groups of discrete frequencies, the group being separated by harmonics of the line frequency (i.e. even harmonics of half the line frequency) as shown in Fig. 1. This occurs because the picture is scanned periodically line by line with considerable redundancy and produces a line spectrum approximating to a Fourier series. The coloring information is *frequency-interleaved* between the spectrum lines of the black-and-white picture at odd harmonics of half the line frequency (i.e. at a harmonic plus half a harmonic).



1 *Energy concentrations in a television signal*

Upper numbers are harmonics of the line frequency; lower numbers harmonics of half the line frequency.

Black-and-white receivers of this signal display only a monochrome picture because the interleaved color signal tends to cancel itself. Fig. 2 explains how this occurs. Fig. 2(*a*) shows a line whose modulation frequency occurs at an even harmonic of half the line frequency. By definition the line period (63·5 microsec) contains an integral number of whole cycles of the modulation. Successive lines, therefore, repeat in phase, and the first line of the next picture (line 526) reinforces line 1. On the other hand, Fig. 2(*b*) shows a signal due to color information. As stated above, this signal has a frequency which is an odd harmonic of half the line frequency. By definition a line period contains an extra half-cycle. This extra half-cycle causes a phase reversal of the added



2 *Cancellation of coloring information*

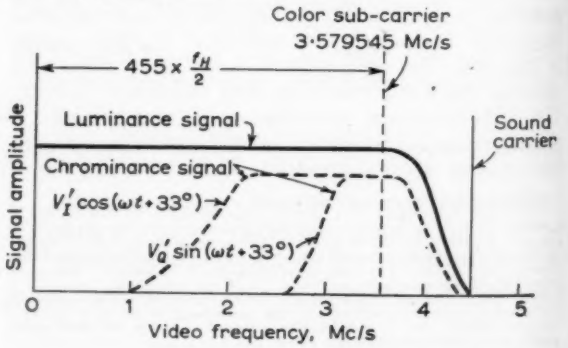
(*a*) Even harmonics of half the line frequency reinforce each other on successive scanning of the same line.
(*b*) Odd harmonics of half the line frequency cancel out.

information on successive lines within each frame (i.e. lines 1, 3, 5, etc., in frame 1 and lines 2, 4, 6, etc., in frame 2), which tends to cancel when viewed at a distance. In addition, line 526 (the top line of the second picture) cancels the information on line 1.

The cancellation would be complete if the system were linear, and if the eye had complete retentivity from picture to picture. In practice the system is only approximately linear, and the eye cancels only that part of the color modulation which it remembers from picture to picture, and thus only a part of the amplitude of the color information cancels itself out. If the coloring signal is transmitted at too high a level, the peaks of the color sub-carrier and its sidebands appear as dots in the colored parts of the transmitted picture when viewed on a monochrome receiver.

3 *Idealized picture transmission characteristics*

The signal amplitudes are not to scale.



* The definition of *chrominance* is as follows:
The colorimetric difference between any color and a reference color of equal luminance, the reference color having a specified chromaticity.
Note.—In N.T.S.C. transmission, the specified chromaticity is the zero sub-carrier chromaticity.

To transmit the color sub-carrier at high enough amplitude for adequate signal/noise ratio and yet make the dot pattern invisible, the frequency chosen for the sub-carrier is high enough (3·579 545 Mc/s) to be attenuated considerably by existing monochrome receivers. This frequency is equal to the 455th harmonic of half the line frequency (see Fig. 3).

Luminance Signal

The luminance signal voltage V_Y can be obtained direct from a camera whose output is proportional to luminance. More usually it is made up by combining voltages (V_R, V_G and V_B, related to the red, green and blue reproducing primaries) which are derived from a three-color camera. In the second method the three components V_R, V_G and V_B are combined in proportion to their contribution to the total luminance.

The luminance signal is made up as follows:

$$V_Y = 0{\cdot}59V_G + 0{\cdot}30V_R + 0{\cdot}11V_B \quad . \quad . \quad (1)$$

This expression indicates that the green, red and blue reproducing primaries* contribute respectively 59, 30 and 11% of the luminance of white (defined by the chromaticity co-ordinates $x = 0{\cdot}310$, $y = 0{\cdot}316$, i.e. Standard Source C). Note that the sum of the numerical factors in equation 1 is unity.

The system is so proportioned that white (Standard Source C) is produced when $V_R = V_G = V_B$. Hence for white light, by substituting in equation 1,

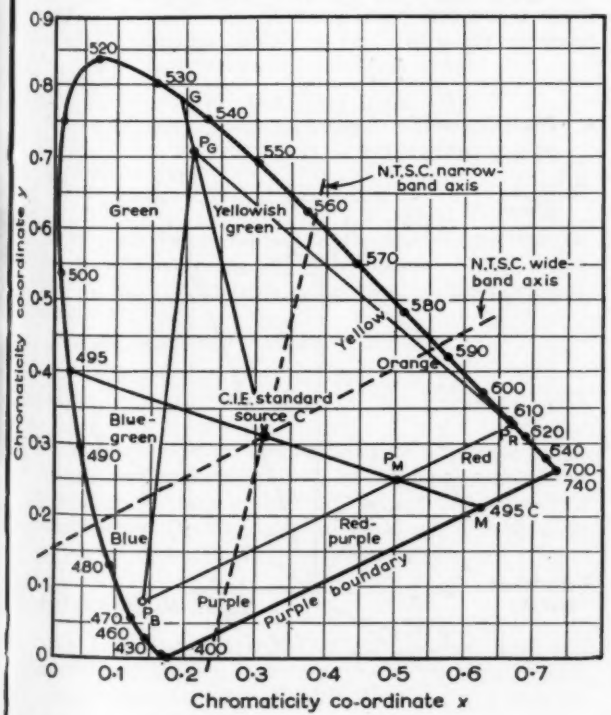
$$V_Y = V_R = V_G = V_B \quad . \quad . \quad . \quad (1a)$$

* The standard reproducing primaries P_R, P_G, P_B, are shown in Fig. 4.

4 *C.I.E. chromaticity diagram*

N.T.S.C. primaries are as follows:

	x	*y*
Red P_R	0·670	0·330
Green P_G	0·210	0·710
Blue P_B	0·140	0·080
Standard source C.. ..	0·310	0·316



Chrominance Signal

While the eye is much more sensitive to detail in luminance than in chromaticity, its resolving power is appreciably greater for colors along the orange-to-cyan than along the greenish-yellow-to-purple chromaticity axes. These axes are shown as dashed lines in Fig. 4. Voltages corresponding to the orange-to-cyan and greenish-yellow-to-purple axes are called respectively V_I and V_Q. They can be derived from cameras whose outputs V_R, V_G and V_B are respectively proportional to the intensities of the red, green and blue primaries by mixing these voltages in the following proportions:

$$V_I = -0{\cdot}27(V_B - V_Y) + 0{\cdot}74(V_R - V_Y) \quad . \quad (2)$$

$$V_Q = 0{\cdot}41(V_B - V_Y) + 0{\cdot}48(V_R - V_Y) \quad . \quad (2a)$$

On white V_I, V_Q, $V_B - V_Y$, and $V_R - V_Y$ are equal to zero. This can be seen by substituting equation 1*a* in equations 2 and 2*a*.

Gamma Correction

The luminous intensity I of cathode-ray-tube displays varies with the impressed voltage V as follows:

$$I = KV^{\gamma}$$

where γ lies between 2 and 3 and K is a constant.

For this reason, the primary voltages are intentionally distorted in the transmitter by being raised to the $1/\gamma$ power to make the luminous intensity directly proportional to the impressed voltage; thus

$$I = K(V^{1/\gamma})^{\gamma} = KV$$

For simplicity $V^{1/\gamma}$ is written as V' so that the quantities in equations 1, 2 and 2*a* are rewritten as follows:

$$V'_Y = 0{\cdot}59V'_G + 0{\cdot}30V'_R + 0{\cdot}11V'_B \quad . \quad . \quad (1b)$$

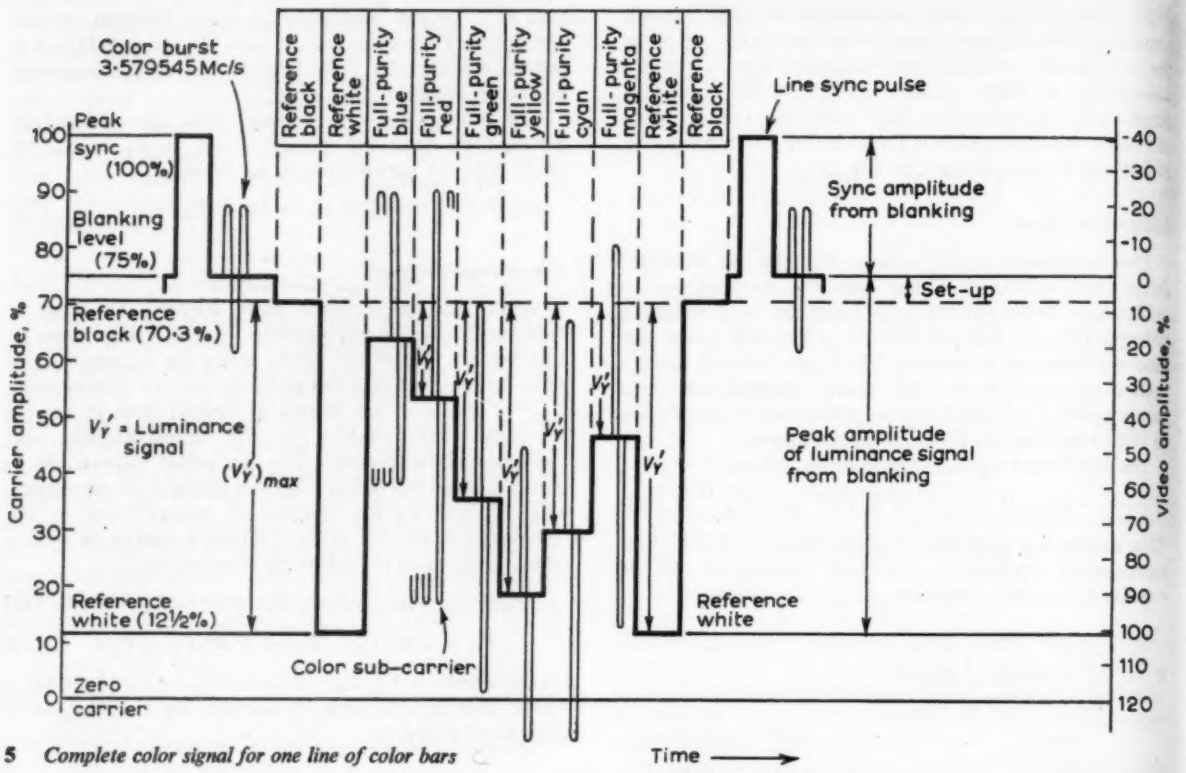
$$V'_I = -0{\cdot}27(V'_B - V'_Y) + 0{\cdot}74(V'_R - V'_Y) \quad . \quad (2b)$$

$$V'_Q = 0{\cdot}41(V'_B - V'_Y) + 0{\cdot}48(V'_R - V'_Y) \quad . \quad . \quad (2c)$$

Prior to modulation on the chrominance sub-carrier, V'_I and V'_Q are bandwidth limited to about 1·3 and 0·5 Mc/s respectively, to eliminate crosstalk between them as explained later.

Transmitter

It is the purpose of the transmitter to emit three quantities, V'_Y, V'_I, V'_Q, independently of each other.



5 *Complete color signal for one line of color bars*

The luminance signal V_Y' is transmitted in the same manner as any monochrome television signal.

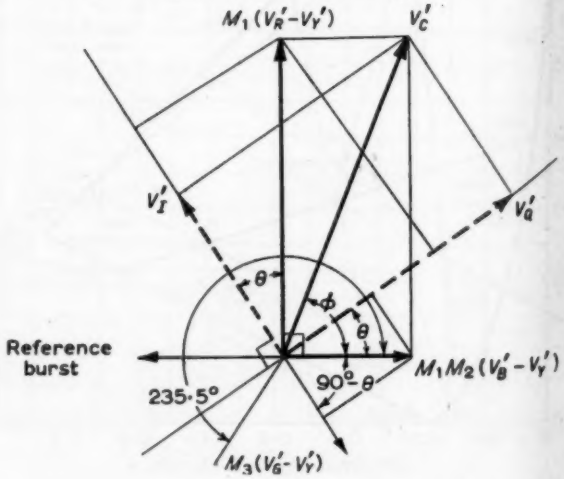
The transmission of V_I' and V_Q' independently is performed by a simple technique which was little known until recently. This technique is known as *synchronous modulation* and allows the transmission of two independent modulations on a single carrier. It is possible to do this since one signal can be transmitted as amplitude modulation of the carrier and the other signal as phase modulation. It will be shown that the method employed here results in the transmission of (*a*) purity × luminance as amplitude modulation of the color sub-carrier, and (*b*) dominant-wavelength (hue) as phase modulation of this same carrier. Since the actual color (hue) depends on the phase of the sub-carrier, a reference phase corresponding to yellow (the reference hue) is transmitted to allow measurements of the deviation of the color signal from the reference phase. The reference phase is transmitted by a "burst" of a few cycles of the reference signal on the back-porch of the horizontal synchronizing pulse (see Fig. 5).

Actually the double modulation is carried on by resolving the color sub-carrier into two components differing in phase by 90°. The phase modulation is then obtained by changing the relative amplitudes of the components. The sub-carrier of frequency 3·579 545 Mc/s ($\omega = 2\pi \times 3\,579\,545$ rad/sec) is split into two components of phases sin ωt and cos ωt which are respectively modulated by $(V_B' - V_Y')$ and $(V_R' - V_Y')$. The reference phase is $-\sin \omega t$, which corresponds to a

6 *Phase diagram for chrominance signal*

$$V_C' = M_1[M_2^2(V_B' - V_Y')^2 + (V_R' - V_Y')^2]^{1/2} \angle \phi = (V_Q'^2 + V_I'^2)^{1/2} \angle \phi$$

$$\phi = \arctan \frac{V_R' - V_Y}{M_2(V_B' - V_Y')} = \theta + \arctan \frac{V_I'}{V_Q'} \qquad \theta = 33°$$



color signal $-(V'_B - V'_Y)$. It is of course possible to modulate two other quadrature components of the sub-carrier with V'_Q and V'_I. For this V'_Q is modulated on a component of phase $\sin(\omega t + \theta)$ and V'_I on one of phase $\cos(\omega t + \theta)$, where θ is to be determined. Either method of modulation must obviously result in the same color sub-carrier. Thus, by expressing this discussion in mathematical form, it is seen that the color sub-carrier V'_C is given by

$$V'_C = M_1[M_2(V'_B - V'_Y)\sin\omega t + (V'_R - V'_Y)\cos\omega t]$$
$$= V'_Q \sin(\omega t + \theta) + V'_I \cos(\omega t + \theta) \quad . \quad . \quad (3)$$

where M_1 and M_2 are constants whose implication is explained below.

Equation 3 is made clearer by the phase diagram of Fig. 6. The modulated color sub-carrier V'_C is seen to be equally well resolved into two quadrature components $M_1M_2(V'_B - V'_Y)$ and $M_1(V'_R - V'_Y)$ or into two others V'_Q and V'_I, the two sets of quadrature components being separate from each other by the angle θ which transforms one into the other. Fig. 6 shows that

$$V'_Q = M_1M_2(V'_B - V'_Y)\cos\theta + M_1(V'_R - V'_Y)\cos(90° - \theta) \quad . \quad (4a)$$

$$V'_I = -M_1M_2(V'_B - V'_Y)\cos(90° - \theta) + M_1(V'_R - V'_Y)\cos\theta \quad . \quad (4b)$$

and θ may be found by substituting equations 2*b* and 2*c* in these two equations.

M_1 is proportional to the amplitude, and M_2 determines the relative composition, of the color sub-carrier. In N.T.S.C. color,

$$M_1M_2 = 1/2{\cdot}03 \text{ and } M_2 = 1/1{\cdot}14$$

With these values for M_1M_2 and M_2, $\theta = 33°$.

From Fig. 6 it can be seen that

$$\tan\phi = \frac{V'_R - V'_Y}{M_2(V'_B - V'_Y)} \quad . \quad . \quad . \quad (5a)$$

The angle ϕ thus depends on the relative amplitude of the two components of chrominance $V'_R - V'_Y$ and $V'_B - V'_Y$ and so is entirely a function of the dominant wavelength (hue).

The amplitude of V'_C can be written as

$$|V'_C| = \left\{\frac{M_1[M_2^2(V'_B - V'_Y)^2 + (V'_R - V'_Y)^2]}{V'_Y}\right\}V'_Y \quad . \quad (5b)$$

The bracketed term is the ratio of the amplitude of the chrominance (coloring signal) to the amplitude of the luminance V'_Y and is therefore related to purity. The amplitude of the chrominance signal can therefore be said to be related to *purity* × *luminance*.

Synchronous Detection

To extract a component of chrominance from the color signal, the latter is heterodyned in the receiver with a locally generated signal which has the same frequency and phase as the carrier component carrying the desired modulation. This process is sometimes called synchronous detection and must not be confused with other forms of detection which recover the modulation envelope. The detection process is explained in more detail later on.

Complete Color Signal

The complete color signal V_m is the sum of the luminance and chrominance signals:

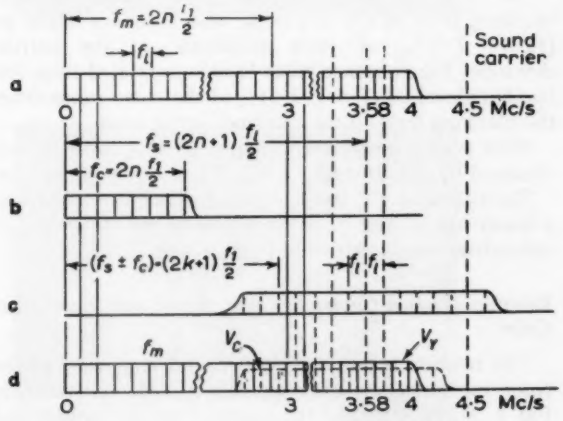
$$V_m = V'_Y + M_1[M_2(V'_B - V'_Y)\sin\omega t + (V'_R - V'_Y)\cos\omega t] \quad . \quad (6a)$$
$$= V'_Y + [V_Q \sin(\omega t + 33°) + V'_I \cos(\omega t + 33°)] \quad . \quad . \quad . \quad . \quad (6b)$$

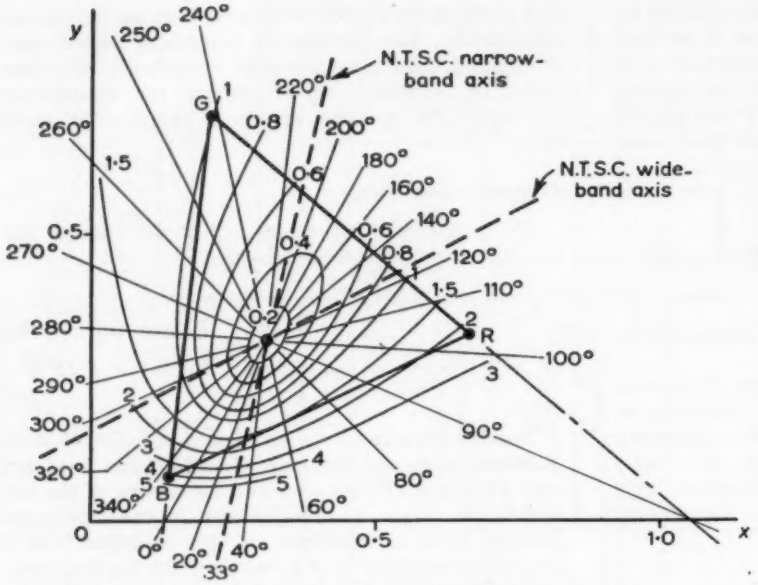
The chrominance sub-carrier frequency (3·579 545 Mc/s) is chosen as an odd harmonic of half the line frequency and therefore falls between two harmonics of the line frequency to give it low visibility in the reproduced picture. Since its sidebands are also separated from it and from each other by a harmonic of the line frequency, all chrominance sidebands will be interlaced within the luminance frequencies. This is illustrated in Fig. 7. Fig. 7(*a*) represents the luminance spectrum with the vertical lines denoting even harmonics of half the line frequency. Fig. 7(*b*) illustrates a video-frequency chrominance component such as V'_I. It also consists of even harmonics of half the line frequency. The signal of Fig. 7(*b*) is modulated on a sub-carrier of frequency f_s (= 3·58 Mc/s) which is interleaved between harmonics of the line frequency. The sidebands of the modulation

---

7 *Band sharing by monochrome and color signals*

(*a*) Luminance signal.
(*b*) Video-frequency chrominance component.
(*c*) Modulation sidebands.
(*d*) Frequency interleaving.
f_c = chrominance video frequency.
f_l = line frequency.
f_m = luminance modulation frequency.
f_s = sub-carrier frequency.
n and k are integers.





8 *Map of normalized N.T.S.C. chrominance signal for linear operation*

[Taken from N.T.S.C. Panel 12, Paper No. D/794, by F. J. Bingley, and reproduced by courtesy of the Philco Corporation.]

are shown in Fig. 7(*c*). They are seen in Fig. 7(*d*) to be frequency-interleaved between the luminance components.

The spectrum of the complete video color signal is shown in Fig. 3.

Instantaneous Value of Complete Color Signal

Fig. 5 shows a plot of the instantaneous values of the complete color signal for one scanning line when reproducing vertical bars of color. The bars are respectively black, peak white, and saturated blue, red, green, yellow, cyan, and magenta (purple). Intensities are measured downward from the black level.

The N.T.S.C. has specified these values as: the blanking level at $(75 \pm 2{\cdot}5)\%$, and reference white at $(12{\cdot}5 \pm 2{\cdot}5)\%$, of peak amplitude of the carrier envelope. The reference black level is separated from the blanking level by $(7{\cdot}5 \pm 2{\cdot}5)\%$ of the video range from the blanking level to the reference white level.

With peak white taken as equal to 1·0, the bars are obtained by substituting $V'_G, V'_R, V'_B = 1$ in equation 6*a*.

The values of V'_Y, the luminance signal, are plotted as a heavy line in Fig. 5. A few cycles of the chrominance sub-carrier are shown with V'_Y as a base.

Relation between Complete Color Signal and Reproduced Color

The relation between the phase and amplitude of the color sub-carrier and the reproduced color is shown in Fig. 8. This is a map of the color sub-carrier's phase and relative amplitude (V'_C/V'_Y) on the C.I.E. chromaticity diagram. The radial lines are loci of constant phase deviation (ϕ in equation 5*a*) of the chrominance sub-carrier. The concentric lines represent constant values of V'_C/V'_Y.

Generation of the Complete Color Signal

Fig. 9 shows a block diagram of a transmitter to generate and transmit the complete color signal. The color camera supplies three simultaneous, instantaneous voltages V_G, V_R and V_B which are proportional to the tristimulus values G, R and B of the color of the picture element being scanned, and are adjusted to equality when viewing Standard Source C. These three voltages are individually gamma corrected to V'_G, V'_R and V'_B. The luminance signal V'_Y is formed by adding the three signals in the proportions of 0·59, 0·30 and 0·11, which are their contributions to luminance as previously stated.

The luminance signal is also combined with V'_R and V'_B to form the color difference signals $V'_R - V'_Y$ and $V'_B - V'_Y$. These two signals are then combined, in matrix (i.e. mixer) 1 to form V'_I and V'_Q, which in turn are frequency limited to 1·3 Mc/s and 0·5 Mc/s, respectively. V'_I and V'_Q are then recombined to $V'_R - V'_Y$ and $V'_B - V'_Y$ in the inverse matrix 2. The two matrices cancel each other for color-difference signals below 0·5 Mc/s. Above that frequency, the bandwidth information for V'_I and V'_Q is carried by $V'_R - V'_Y$ and $V'_B - V'_Y$ acting in concert.

One signal $(V'_B - V'_Y)_1$ is used to modulate in amplitude one component of the color sub-carrier, $\sin \omega t$. The other $(V'_R - V'_Y)_1$ is used to modulate in amplitude a second component of the color sub-carrier $\cos \omega t$, which is in quadrature with the first component. The subscript 1 after the color-difference signals shows that they have been bandwidth limited (i.e. in V'_I and V'_Q). Using $V'_B - V'_Y$ as one of the chrominance components which modulate the transmitter results in some equipment simplification by easing the generation of the color burst, because the latter is specified as having the same phase as the component of the chrominance signal which is modulated by $-(V'_B - V'_Y)$. The modulators should be of the balanced type to suppress the sub-carrier from the output.

The outputs of the two modulators are written simply as $(V'_B - V'_Y)_1 \sin \omega t$ and $(V'_R - V'_Y)_1 \cos \omega t$. They are added in the specified proportion and at the specified level to form the chrominance signal V'_C, as shown in equation 3.

The luminance signal V'_Y is then added to form the complete color signal, which is described by equation 6*a*.

The complete color signal is impressed on the phase-

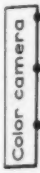
A A COMPLETE COLOR TELEVISION PICTURE PHOTOGRAPHED FROM A DISPLAY

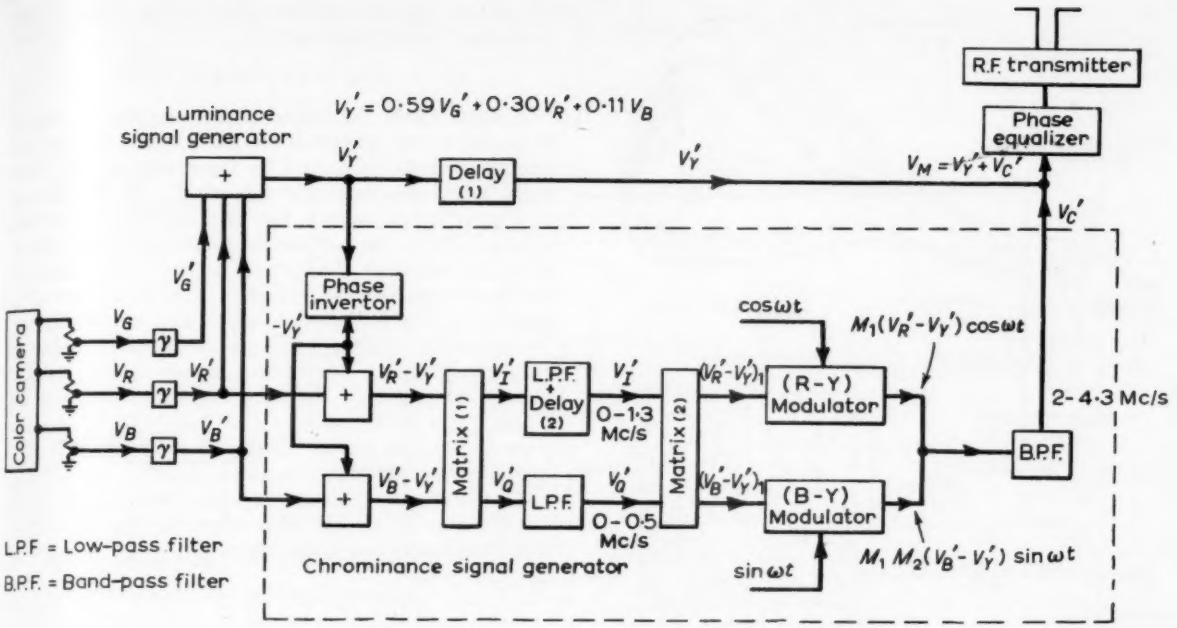
B THE LUMINANCE COMPONENT (BLACK AND WHITE) OF THE COMPLETE PICTURE SHOWN IN 'A'

C THE CHROMINANCE COMPONENT (COLOR) WHICH IS ADDED TO THE LUMINANCE COMPONENT ELECTRICALLY

The background brightness was increased to make visible those parts of the picture which normally would be blacker than black. This made the vertical retrace lines visible and accounts for the blue color of the background which, with proper adjustment, would be infra-black.

D VISIBLE EFFECT OF C.W. INTERFERENCE WHEN USING CONSTANT-AMPLITUDE TRANSMISSION (I.E. NOT USING CONSTANT-LUMINANCE TRANSMISSION). THE ANNOYANCE OF BARS IS REDUCED ABOUT 8 DB WITH CONSTANT-LUMINANCE TRANSMISSION


Color camera



9 *Block diagram of a typical color transmitter*

The camera is adjusted so that on grey $V_G = V_R = V_B$.

Matrix 1

$$V_Q' = 0{\cdot}48(V_B' - V_Y') + 0{\cdot}41(V_R' - V_Y')$$
$$V_I' = 0{\cdot}74(V_R' - V_Y') - 0{\cdot}27(V_B' - V_Y')$$

Matrix 2

$$V_R' - V_Y = 0{\cdot}63V_Q' + 0{\cdot}95V_I'$$
$$V_B' - V_Y' = 1{\cdot}70V_Q' - 1{\cdot}10V_I'$$

The delays of V_Y', V_Q' and V_I' are equal.

$$V_m = V_Y' + M_1[M_2(V_B' - V_Y')\sin\omega t + (V_R' - V_Y')\cos\omega t]$$
$$= V_Y' + V_C'$$
$$= V_Y' + V_Q'\sin(\omega t + 33°) + V_I'\cos(\omega t + 33°)$$

equalizer unit, whose function is to modify the delay of the low-frequency portion of the monochrome signal with respect to the high-frequency portion, where the color sub-carrier is located, to ensure time coincidence of luminance and chrominance information at the second detector of a typical receiver. This is desirable because the receiver selectivity results in a delay for high modulation frequencies, where the sub-carrier is located, more than for low frequencies. The complete color signal is then applied to the r.f. transmitter, whose useful output is frequency limited in practical receivers, so that vestigial sideband transmission of the color sub-carrier results.

It would, of course, be equally feasible to generate V_Q' and V_I' from V_R' and V_B' in matrices, limit them to the desired bandwidths, and modulate them respectively on $\sin(\omega t + 33°)$ and $\cos(\omega t + 33°)$.

Color Receiver

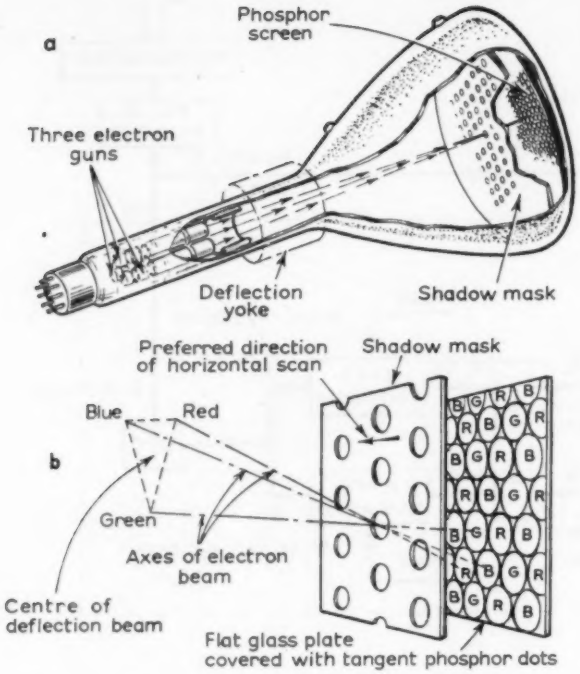
The receiver briefly described here makes use of a tricolor tube with three electron guns (see Fig. 10) which produce red, green and blue light respectively in response to voltages equal to V_R', V_G' and V_B'. Only those functions which differ from those of a monochrome receiver will be described.

Referring to Fig. 11, the complete color signal, $V_Y' + V_C'$, is passed through the luminance amplifiers and 3·57 Mc/s trap to remove the strongest components of the color sub-carrier, which otherwise might result in desaturating the color by increasing the luminance due to the non-linearity of the picture-tube characteristic. The luminance signal is applied, through adders (12, 13, 14) to the three grids of the picture tube. In the absence of a chrominance signal, the luminance signal V_Y' excites the three grids equally to produce a monochrome picture.

The complete color signal is also impressed on a band-pass filter (3) to remove the high-amplitude low-frequency components of V_Y'. The filter output, consisting mostly of the chrominance sub-carrier

$$V_C' = V_Q'\sin(\omega t + 33°) + V_I'\cos(\omega t + 33°),$$

is applied to the V_I' and V_Q' synchronous demodulators (4, 6), to which are also respectively applied local-oscillator voltages $\cos(\omega t + 33°)$ and $\sin(\omega t + 33°)$. These two voltages are derived from the reference burst ($-\sin\omega t$) transmitted on the back porch of the horizontal synchro pulses (5). The two synchronous demodulators (4, 6) produce respectively V_I' and V_Q' in a manner described below. These signals are bandwidth limited to 1·3 and 0·5 Mc/s respectively (7, 8) and combined in the R–Y, B–Y and G–Y matrices (9, 10, 11) in the proportions shown at the lower left of Fig. 11 to



10 *Three-gun shadow-mask tube [after H. B. Law]*

(*a*) Diagram of the tube.
(*b*) Geometrical relation between the electron beams, shadow mask and phosphor screen.

---

produce $V'_R - V'_Y$, $V'_B - V'_Y$ and $V'_G - V'_Y$. These voltages are in turn added (12, 13, 14) to V'_Y to produce V'_R, V'_B and V'_G. The picture tube then reproduces red, green and blue light, which is linearly related to that picked up by the color camera:

$$I_{red} = K_1(V'_R)^\gamma = K_1 V_R \text{ [etc.]}$$

The scene before the camera is therefore reproduced in its original color.

Synchronous Detection

A synchronous demodulator functions by means of the principle of a zero-beat heterodyne, which is illustrated in Fig. 12. An input signal $V(t) \sin \omega t$, is applied to one grid of a multi-grid tube such as American type 6AS6. A phase-reference signal which has the same frequency, but which may differ in phase, $2 \sin (\omega t + \theta)$, is applied to another grid. The plate current is proportional to the product of two voltages and is

$$i_p = 2KV(t) \sin \omega t \sin (\omega t + \theta)$$

The product of the two sines here gives

$$i_p = 2KV(t)[\tfrac{1}{2} \cos \theta - \tfrac{1}{2} \cos (2\omega t + \theta)]$$

The double-frequency term, $KV(t) \cos (2\omega t + \theta)$, is filtered out by the low-pass filter in the plate of the modulator which passes only

$$i_p = KV(t) \cos \theta$$

In other words, the output of the demodulator is proportional to the amplitude of the modulation $V(t)$ on the input signal multiplied by the cosine of the phase angle θ between the color sub-carrier and the heterodyning (reference) signal. The plate current is therefore proportional to the component of the color sub-carrier along the reference direction. The two components of the chrominance signal, V'_I and V'_Q, modulate two components of the sub-carrier which are in quadrature. The color-difference signals can therefore be separated by heterodyning the chrominance signal—one by a signal having the phase of the chrominance component on which V'_I is modulated [i.e. $\cos (\omega t + 33°)$], and the other by a signal having the phase of the chrominance component on which V'_Q is modulated [i.e. $\sin (\omega t + 33°)$].

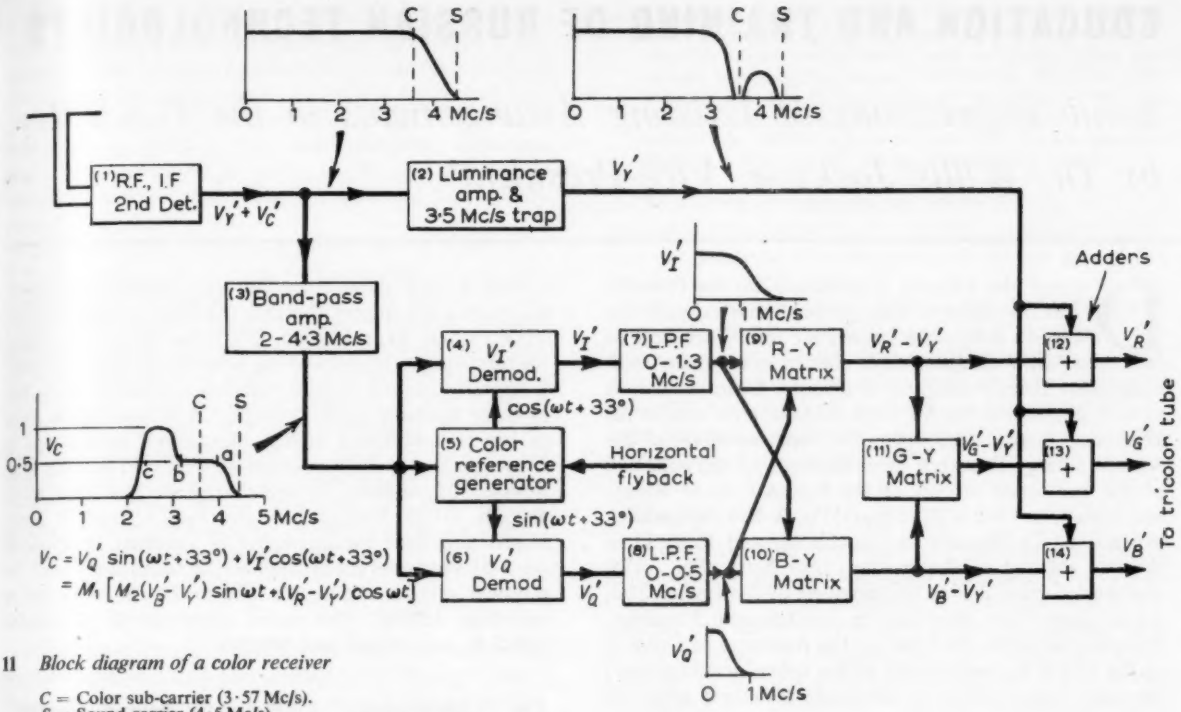
If, however, the heterodyning signal has a phase which is other than 0° or 90° with respect to the two color-difference components, the output will be a mixture of the two.

Quadrature Crosstalk

The chrominance sub-carrier is chosen high in frequency to help reduce its visibility in monochrome receivers which attenuate high video frequencies. The upper sideband is crowded by the sound channel. There is no such limitation for the lower sideband so that it is desirable to transmit a lower sideband of greater bandwidth than the upper one for the maximum visible color detail. The signals V'_I and V'_Q can be kept separate only if both produce symmetrical sidebands about the color sub-carrier. Single-sideband components in V'_I or V'_Q can crosstalk on each other to give color contamination along color edges. This is prevented by transmitting the signal V'_Q with only the bandwidth which can be accommodated with symmetrical sidebands. This amounts to about 0·5 Mc/s. It does not crosstalk on the signal V'_I, which is transmitted with lower sideband much wider than the upper one, and the single-sideband portion (above 0·5 Mc/s approximately) does crosstalk on V'_Q. This crosstalk consists of components above 0·5 Mc/s appearing in the output of the V'_Q demodulator. However, these are filtered out by a low-pass filter in the demodulator output [(8) in Fig. 11]. The output of the V'_I demodulator produces a V'_I signal which can extend to 1·3 Mc/s or higher.

Constant-Luminance Transmission

Studies of flicker using lights having different colors show that the eye is less sensitive to chromaticity than to luminance fluctuations. This suggests that the conversion of noise and other perturbations from luminance to color, wherever possible, may result in a reduction of their visible effect. Data from a small group of observers



11 *Block diagram of a color receiver*

C = Color sub-carrier (3·57 Mc/s).
S = Sound carrier (4·5 Mc/s).
Tricolor tube is adjusted to produce Standard Source C when $V_R' = V_G' = V_B' = V_Y'$.

Matrices

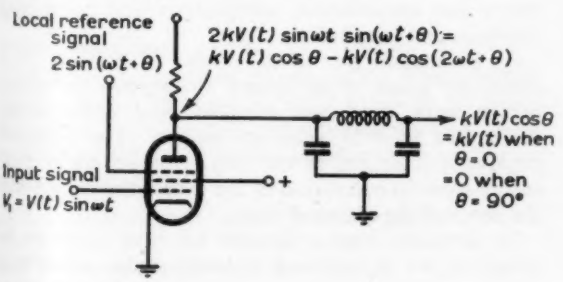
(9) $V_R' - V_Y' = 0{\cdot}63V_Q' + 0{\cdot}95V_I'$
(10) $V_B' - V_Y' = 1{\cdot}70V_Q' - 1{\cdot}10V_I'$
(11) $V_G' - V_Y' = -0{\cdot}51(V_R' - V_Y') - 0{\cdot}19(V_B' - V_Y')$

indicated that about 8 dB more noise could be tolerated for the same degree of annoyance when the noise had only chromaticity fluctuations.

The monochrome channel of a color receiver is no more subject to noise or interference than a monochrome receiver of the same resolution. However, these perturbations may affect the color channel to an appreciable extent unless suitable precautions are taken. The demodulators heterodyne interference, noise, and components from the luminance signal whose frequencies are close to that of the sub-carrier, to lower frequencies, where they produce coarser and more visible patterns.

The visibility of such interference can be greatly reduced by so proportioning the signal that the combined outputs of the demodulators result in no luminance fluctuation. When this is done, the beat note is one of chrominance only and is greatly reduced in visibility. It is for this reason that the complete color signal is transmitted in such a manner that the monochrome signal supplies all the luminance information while the color sub-carrier supplies only variations in chrominance. This is called constant-luminance operation.

12 *Principle of synchronous demodulation*



Advantages of N.T.S.C. Signal

A system using these principles is capable of producing color television pictures with practically the full resolution of which monochrome television is capable. In addition it can transmit all the color information that the eye can resolve. This transmission takes place within the bandwidth now allotted to black-and-white television.

Existing monochrome channels are, therefore, adequate for color. Transmitters can readily be converted to color transmission, which can be received, as a monochrome picture, on an existing black-and-white receiver without altering the receiver in the slightest degree. Likewise monochrome transmissions can be received on color receivers. This has been accomplished by designing the system to take into account the properties of the viewer's eye, which is the actual terminal equipment of the system.

EDUCATION AND TRAINING OF RUSSIAN TECHNOLOGISTS

Some Impressions of Existing Arrangements in the U.S.S.R.

*by Dr. Willis Jackson, Vice-President**

DURING the Geneva Conference on the Peaceful Uses of Atomic Energy held last August the Russian delegation invited Sir John Cockcroft to visit their 5 MW nuclear power station in company with some other British delegates at Geneva. Unfortunately it proved impossible for Sir John to take part and in his absence the party, comprising five representatives of the Atomic Energy Research Establishment at Harwell, two of the Industrial Group of the U.K.A.E.A. at Risley, and myself, was led by his deputy, Dr. B. F. J. Schonland. We arrived in Moscow via Stockholm and Helsinki in the late evening of Wednesday, 16th November, 1955, and started back during the morning of November 21st. At the airport we were met by Academician Topchiev, Principal Scientific Secretary of the Academy of Sciences of the U.S.S.R., and several of his fellow academicians; we owe them a debt of gratitude for their generous hospitality to us throughout our stay and their consideration in arranging the programme of visits to meet our wishes within the limited time available. The whole party went to the nuclear power station, situated some 70 miles from Moscow, but the remaining visits were made in groups of two or three and covered Research Institutes of the Academy devoted to chemistry, physics, metallurgy and electrical power generation and transmission, a large particle accelerator and one of the higher technical institutes of Moscow, the Bauman Institute of Mechanical Engineering. These, combined with three evenings of ballet and one of opera, a tour of the Kremlin including the Lenin–Stalin tomb, and a succession of sumptuous meals and their associated speeches, left no time for relaxation and little for sleep, but made up an experience which will remain vivid for a long time.

Because of the purpose and the shortness of the visit we could not unfortunately gain full information about facilities available in the U.S.S.R. for the education and training of scientists and technologists, but the following limited data are likely to be of some interest and value.

The Bauman Higher Technical Institute of Mechanical Engineering was said to be representative of the 30 engineering schools in Moscow which are providing a 5½-year full-time course starting normally at 17, though it is evidently larger than most of them. The student population of the Bauman Institute is 10 500, of whom 30% are girls. The other 29 engineering schools deal with different branches of engineering. Unfortunately we did not obtain particulars of the subdivision of the subject among these essentially monotechnic Institutes, but gained the impression that the total number of their students was over 100 000. To these should be added the numbers of those following science courses at Moscow University, of total student population around 22 000, and of those studying other branches of technology in some of the 50 additional higher educational institutions in Moscow. As a specific example we were told that the total number of students of metallurgy in that city alone exceeds 10 000. Though no more than a guess, it seems improbable that the aggregate of students in Moscow on 5–5½-year courses in engineering technology and the physical sciences relevant to it from the age of 17 can be less than 150 000. The figure suggested to us for the U.S.S.R. as a whole was 500 000.

The "Undergraduate" Course at the Bauman Institute

The work of the Bauman Institute is divided among six faculties dealing respectively with general mechanical technology, thermal and hydraulic machines, precision instruments, transport machines, metal technology and machine-shop practice. Each faculty provides for a number of still more specialist subdivisions in the final stages of the course, giving 23 possible specialist selections in all. We were supplied with the time-tables of each of these alternatives, and those for three aspects of turbine construction are given in full in the table. The curricula of all the courses are substantially the same for the first three years (subjects 1–22). They differ as between faculties during the fourth year, and as between the 23 specialties during the concluding 1½ years. Examples of the other specialties are technology of the casting and working of metals, heat treatment of metals, equipment and machines for testing metals, thermo-technical measuring and regulating apparatus, applied metrology, hoisting and transporting machines and appliances, technology of welding production, boiler design and construction, refrigeration and compressor machines and installations.

As an integral part of the course all students spend about 200 hours in the school workshops—the quality of the work done was excellent—and eight months during the final 2½ years in industry. The industrial training is organized by the staff of the school so as to ensure close co-ordination of the experience gained with the needs of the course of study.

In particular when a decision has been taken on the subject of the project—e.g. a design study—which is to

* This article was originally submitted by Dr. Willis Jackson to The Institution on the 20th December, 1955.

constitute a student's "diplom-arbeit" and on which he will concentrate during the concluding 4½ months of his course, arrangements are made for him, or her, to spend two months in a department of industry concerned with this class of work. Several of these design studies were shown to us. They incorporated complete drawings, numbering sometimes as many as 20, and I have no hesitation in saying that both their scale and their quality were of a very high order.

The outstanding impression gained was of a staff that is in intimate contact, and well acquainted, with the contemporary problems of productive industry, and that is successfully introducing an awareness of these problems and of the techniques for resolving them into the Institute's teaching work—in fact we sensed a highly developed and successful co-ordination of the work of the Institute and of the industry which it serves. This impression was strengthened by what we saw of the research and development work and by the display in a permanent exhibition of examples of instruments, apparatus, machine tools, etc., which had been designed and constructed within the school.

Standard of Entry

It will have become evident that the courses in the Bauman Institute, and presumably in the other engineering schools of Moscow, are much more technical in their objectives than are our own courses—whether university or technical college—leading to Graduate Membership of one of the three major engineering Institutions. Unfortunately we were unable to obtain specimen examination papers from which the standard of entry and ultimate analytical achievement might have been judged. We were told, however, that the students have no knowledge of the calculus at entry, and it may be noted from the table (p. 100) that the formal study of mathematics is discontinued at the end of the third year, and occupies only two hours per week for half of this year. Nevertheless some of the special projects we examined indicated a more advanced knowledge of mathematics than these facts might suggest.

We were informed that the number of applicants for entry is in excess of the number of first-year places by a factor of three and that the selection is based on a competitive examination. The proportion of first-year students required to leave owing to unsatisfactory progress is about 5% and at later stages of the course about 3% per year.

Maintenance Grants

All students attending courses of the kind outlined above receive a maintenance grant to which no means test applies. The value of the grant to engineering students varies from 300 to 600 roubles per month, depending on three considerations:

(i) The year of the course, the value increasing towards the final year.

(ii) The student's progress in the course.

(iii) The particular specialty selected, the special subjects that carry the highest grant being the "harder" or "less attractive" branches of engineering work, such as machine shop and foundry practice at the Bauman Institute. So far as we could ascertain, this was the only form of "persuasion" applied to students. Regrettably, I failed to inquire whether a similar incentive is used to attract students towards the advanced study of science and technology as against arts subjects.

The scheme of maintenance grants also provides for the award of Stalin prizes of value 800 roubles per month, and one hundred of these prizes are in the gift of the Bauman Institute.

Since it was not possible to study the circumstances of student life in Moscow I find it difficult to translate the above figures into British currency. However, the assumption of 40 roubles/£ as a reasonable rate of exchange gives £90–£240 per year as the range of value of grants, from which the student of the Bauman Institute must pay an annual tuition fee of £20.

Military Service

Having in mind the attention recently focused in Britain on military service, I was interested to learn that the students of the engineering Institutes are either excused this service *in toto* or required to undergo only a short period of training. This led naturally to the question of how the technical units of the armed forces are staffed, and the answer received was that this takes place through the military academies, recruitment to which was said to be distinct from that to the engineering and similar Institutes. Whether or not this is a complete answer, it nevertheless suggests—admitting still further uncertainty as to standard of attainment, and therefore as to the basis of comparison with ourselves—that the total numbers of students given earlier in the article may be substantially on the low side.

More Advanced Study and Research

The preceding account has failed to clarify, and indeed I am not able fully to do so, how the equivalent of our own honours degree men are produced. Yet the quality of the work being done in the Research Institute we visited left us in no doubt of their existence.

We were told at the Bauman Institute that "post-graduate" work formed an important part of its activities and of those of similar teaching Institutes. The number of its post-graduate students is at present 240—some 2½% of the student body—and the duration of their further study and research prior to submission for a "Candidature" qualification is three years. Some 40% of these students continued direct from completion of a 5½-year undergraduate course, but the remaining 60% registered after a period of industrial employment. Many of each group had undertaken their earlier studies at another Institute.

It seems, however, that the post-graduate contribution of the teaching institutions is probably small compared with that of the Research Institutes of the Academy of Sciences of the U.S.S.R. and of the similar Institutes of the

THE BAUMAN HIGHER TECHNICAL INSTITUTE, MOSCOW

The Institute awards a specialized qualification in Mechanical Engineering, the period of study being 6 years 5 months.

STUDY PLAN AND CURRICULUM FOR **TURBINE CONSTRUCTION** (Confirmed by the Deputy Minister for Higher Education of the U.S.S.R., V. A. Kirilin, on the 15th March, 1955.)

In this subject there are three possible specialties: (*a*) Design and Manufacture of Steam Turbines; (*b*) Design and Manufacture of Stationary and Mobile Gas Turbines; (*c*) Design and Manufacture of Aviation Gas Turbines.

ITEM NO.	TITLE OF COURSE	DISTRIBUTION OF SEMESTERS		COURSE PROJECTS AND COURSE WORK	TIME ON COURSE														
						DISTRIBUTION BY TYPE OF WORK				DISTRIBUTION BY YEARS AND SEMESTERS									
										Year I		Year II		Year III		Year IV		Year V		Year VI
		Exams	Credits		TOTAL	Lectures	Laboratory Classes	Practical Work	Projects and Course Work	1 Sem. 18 Wk.	2 Sem. 16 Wk.	3 Sem. 17 Wk.	4 Sem. 16 Wk.	5 Sem. 17 Wk.	6 Sem. 16 Wk.	7 Sem. 14 Wk.	8 Sem. 13 Wk.	9 Sem. 14 Wk.	10 Sem. 13 Wk.	11 Sem.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
					Hours					Hours per week										
1	Fundamentals of Marxism–Leninism	2, 4	1, 3		252	160		92		4	3	4	4							
2	Political Economy	6, 8	5, 7		140	100		40						2	3	2	3			
3	Industrial Organization, Economics and Planning	10			95	80		15										4	3	
4	History of Technology		10		39	29		10											3	
5	Foreign Language	4	1, 2, 3, 6, 8		134			134		2	2	2	2							
6	Higher Mathematics	1, 1, 2, 3	4, 6		420	242		178		8	8	4	3		2					
7	Physics	2, 3, 4	2, 3, 4		245	131	98	16			6	5	4							
8	General Chemistry	1, 2	1, 2		120	70	50			4	3									
9	Descriptive Geometry	1			90	54		36		5										
10	Drawing and Machine Drawing		1, 2, 3, 4		188			188		5	2	2	2							
11	Theoretical Mechanics	2, 3, 4			215	115		100			3	6	4							
12	Strength of Materials	3, 4	3, 4, 5		232	133	33	66				6	6	2						
13	Theory of Mechanisms and Machines	5	4, 5	4, 5	197	80	20	37	60				7	5						
14	Details of Machines	5	6	6	215	85	17	17	96					7	6					
15	Fundamentals of Interchangeability and Technical Measurement	5			34	24	10							2						
16	General Electro-Technics	7, 8	7, 8		162	100	32	30								6	6			
17	Thermodynamics and General Thermo-Technics	5, 6, 7	7		233	199	14	20						5	4	6				
18	Hydraulics and Hydraulic Machines	5	5		102	68	15	19						6						
19	Introduction to Metallurgy, Heat Treatment and Constructional Materials	6	6, 10		135	90	45								6				3	
20	Technology of Metals	3, 6	1		182	182				2	3	2			4					
21	Workshops		1, 2, 5		204			204		4	4			4						
22	Hoisting, Conveying and Handling Equipment		6, 7	7	116	32			84						2	6				
23	Gas Hydrodynamics	6, 7	7		134	90	16	28							4	5				
24	Technology of Turbine Construction	7			70	60	10									5				
25	Thermal Electric Stations	10			52	52													4	
26	Compressors	8	8, 9	9	78	65	13										6			
27	Construction and Calculation of Steam Turbines	9	8, 9, 10	10	133	93	26	14									7	3		
28	Construction and Calculation of Gas Turbines	8, 9	8, 9	10	190	137	26	27									6	8		
29	Automatic Control and Regulation of Turbines	10	10		65	52	13												5	
30–33	Specialty Disciplines (*listed below*)	9, 10	9, 9, 10, 10		243	198	18	27										9	9	
34	Physical Education and Sport		2, 4		134			134		2	2	2	2							
35	Industrial Safety and Fire Fighting	9			42	32	10											3		
	SPECIALTY (*a*):																			
30	Equipment for Condensation and Heat Transfer	9	10		69	56	13											4	1	
31	Steam Turbine Installations	10	10		78	52	13	13											6	
32	Foundations, Erection and Operation of Turbines		9, 10		54	41	13											2	2	
33	Boilers and Boiler Installations		9		42	35		7										3		
	SPECIALTY (*b*):																			
30	Fuels and Combustion Theory	9	9		98	70	14	14										7		
31	Heat Exchange Equipment		10		39	35	4												3	
32	Erection and Exploitation of Gas Turbines		10		39	39													3	
33	Gas Turbine Installations	10	9		67	54		13										2	3	
	SPECIALTY (*c*):																			
30	Combustion Chambers	9	9		70	42	14	14										5		
31	Aircraft Construction and the Erection and Operation of Aviation Gas Turbine Prime Movers		9		56	48	8											4		
32	Heat Exchangers		10		52	42	10												4	
33	Aviation Gas Turbine Installations	10	10		65	52		13										5		
	TOTALS				4891	2753	466	1432	240	36	36	33	34	33	31	30	28	27	27	
	No. of Course Projects	6											1	1	1	1		1	1	
	No. of Examinations			45						4	5	5	5	5	5	4	4	4	4	
	No. of Credits		54							6	6	5	6	5	5	5	5	5	6	

SPECIAL PROJECT

acader
U.S.S.
Resea
30000
and te
Institu
approv
seem
Depar
but w
selecte
carry
tribut
highe
furthe
in whi
As a
Resea
fessor
this s
Institu
this p
featu
No
"Ho
our c
bene
atten
shall
absen
and
and
how
recei
give
W
refer
Mos
who
univ
insti
mul
inco
stud
the
bloc
their
part
furt
on i
is b
FEB

academies of the constituent republics. The U.S.S.R. Academy is responsible for 100 Research Institutes with a total staff of around 30000, including about 11000 research scientists and technologists. The organization of these Institutes and the committee arrangements for approving their research programmes would seem to be comparable with those of our Department of Scientific and Industrial Research, but with one important difference: this is that selected staff members of the Research Institutes carry the status of professor or lecturer and contribute to the teaching work of the appropriate higher technical schools or of the university, and further that the Institutes are recognized as places in which students may qualify for higher degrees. As an example, the particular metallurgical Research Institute which we visited had 30 professors on its total staff of 700, and some 80 of this staff were registered as higher-degree students. We were told that the total number of such students within the several metallurgical Research Institutes of Moscow was between 300 and 400.

The University of Moscow

This close association of the teaching institutions with the Research Institutes, combined with their association with industry, is likely to be one of the most lasting impressions of my visit. Unfortunately our inquiries did not afford a picture of the relationship between the Research Institutes and industry. All I was able to ascertain on this point was that research departments are a common feature of the larger manufacturing organizations.

Not surprisingly I keep asking myself the question, "How can we develop a more effective co-ordination of our own national effort and resources without loss of the benefits associated with a free society?" I shall make no attempt in these notes to suggest an answer. Nor, in the absence of more reliable data on numbers and standards, shall I try to draw precise comparisons with the scale and character of our own educational effort in science and technology. A precise comparison is unnecessary, however, to add emphasis to the fact, often stated during recent years, that this effort is seriously inadequate and gives cause for grave national concern.

With this in mind it is fitting to conclude with a reference to the new buildings of the University of Moscow, which dominate the centre of the city, and whose central part is shown in the photograph. The university differs from the other higher-educational institutions of Moscow referred to previously in being multi-faculty in both arts and science, though it does not incorporate engineering. Some 6000 of the present student body of 22000 are accommodated in a block of the central building. A separate, almost equally imposing block, is being constructed to house staff members and their families. A large area around the completed or partially constructed buildings has been cleared for further development. Trees and gardens are being planted on it and the outlook from the steps of the main building is both beautiful and exciting.

Let there be no doubt that the Soviet Union regards higher education as supremely important—though its objectives are evidently much narrower than our own—and that already its achievements are extremely impressive.

ADDENDUM

Since completing the above article I have had the opportunity to read a recently published book by Nicholas De Witt of the Russian Research Centre, Harvard University, entitled *Soviet Professional Manpower*.* This scholarly book gives a much deeper insight into educational objectives than could possibly be acquired during a few days' visit and a range of statistics which merit detailed study, but it does incidentally confirm what I have written above. It describes and discusses the work of the following. (*a*) The 33 Soviet Universities. (*b*) The 758 Institutes made up as follows: engineering (177); agriculture (109); medicine and physical culture (88); social economics (35); and teacher training, architecture, languages, graphic and theatrical arts, etc. (349). (*c*) The "Secondary Specialized Institutions," commonly called *Technicums*, which accept students of age 14–16 for a highly technical four-year course, in which about 40% of the time is devoted to practical work within the school, 33% to industrial practice, and the remainder to a continuance of general education and technical instruction.

De Witt states that the enrolment to the engineering Institutes in 1950—the latest year for which he was able to obtain reliable information—was 278300, but that it has increased considerably since that date. He does not give an enrolment figure for the engineering Technicums but suggests that it is substantially higher than for the corresponding Institutes.

Perhaps the most valuable feature of the book is its treatment of the intensive specialization which characterizes the Soviet system of higher education, and of its immediate benefits and possible longer-term consequences.

* Published by the National Science Foundation, Washington, D.C., 1955.

THE START OF THE BRITISH NUCLEAR ENERGY CONFERENCE

A Successful Inaugural Meeting in November

In the autumn of last year the British Nuclear Energy Conference staged a most successful first performance in the home of The Institution of Civil Engineers, where some 1 200 physicists, chemists, and engineers filled the two halls to overflowing. Probably the date itself, the 30th November, 1955, will not be long remembered. Few scientific dates are. But it is significant as witnessing the first meeting of an organization that is clearly destined to grow in importance and activity.

The Chairman of the Board of the Conference, Sir Christopher Hinton, Director of the Industrial Group of the United Kingdom Atomic Energy Authority, opened the proceedings at 2.15 p.m. With him on the dais were the Presidents of the five constituent societies of the Conference, The Institutions of Civil, of Mechanical, of Electrical, and of Chemical Engineers, and The Institute of Physics, with the Secretary of the Conference; there were also many distinguished members of the five societies among the audience.

In his opening speech Sir Christopher welcomed the formation of the Conference, emphasizing that it is a collaborating and co-ordinating, rather than a controlling body. It would not abrogate the existing responsibilities of the constituent societies. He said that nuclear engineering was really only ten years old, and eight of those ten years had been given up to its military side. Nuclear engineering was not a completely new technology: for example nuclear power stations would have strictly conventional equipment as one third of their plant.

The first lecture, which followed immediately, was given by Sir John Cockcroft, President of The Institute of Physics and Director of the Atomic Energy Research Establishment, on "The United Kingdom Atomic Energy Authority and its Functions." He said that the U.K.A.E.A. has three groups: Industrial, Research and Weapons. Both the Industrial and the Research Groups have large staffs working on power projects and associated nuclear technology. The Research Group is responsible for all basic nuclear measurements for work in reactor physics and for designing and operating research and test reactors, such as Bepo for providing neutron beams and radioisotopes and Gleep for proving the quality of uranium and graphite. To provide higher neutron intensity three new heavy-water reactors (one Dido and two Pluto class) are being built at Harwell and Dounreay; they will be used over long periods for testing nuclear fuels. It is likely that this expensive equipment will be owned centrally by the Authority for some time.

Sir John next considered the development of nuclear power reactors. The United Kingdom programme began with the graphite-moderated gas-cooled reactor under construction at Calder Hall, and the first few of the next twelve power stations due to be completed between 1960 and 1965 would be improved versions of this. Reactors giving a higher electrical output per ton of uranium involve the use of water or liquid sodium for heat transfer and these are envisaged for Stage 2 of the programme. Stage 3 of the United Kingdom programme provides for breeder reactors using the uranium-233/thorium or the plutonium-239/uranium-238 fuel cycles, but the development period for these is likely to be long.

Work on the development of a new reactor begins in the Research Group at Harwell with research into the feasibility of a reactor system, and when a system is selected the design is taken over by the Industrial Group, whose Applied Research Department develops the necessary fuel elements. Sir John stressed that industry is associated very closely with the work at all stages.

Development of fuel elements that will withstand the long burn-up period is most difficult. Uranium metal elements, for example, distort under thermal cycling, and the fission process also contributes to this. Heavy- or ordinary-water reactors will probably use uranium oxide, which is not attacked by hot water; sodium-graphite reactors will be able to use uranium metal. Test reactors such as Dido and Pluto are vital for the essential and prolonged testing of fuel elements. The U.K.A.E.A. at present processes spent fuel at Windscale; plutonium, fission products, and spent uranium metal are produced. The cost of the process is much less for large-scale operation.

Sir John mentioned also the Radiochemical Centre at Amersham, whose output of radioactive isotopes is rapidly growing, and the Technological Irradiation Group at Harwell, which aids industry to investigate the application of radiation.

Sir John concluded his admirable lecture by emphasizing the responsibility of the U.K.A.E.A. for collaboration both with other Government organizations and with the United States and Commonwealth countries; for example help is now being given to Australia in the construction of a reactor of the Dido class.

Mr. V. A. Pask spoke next on "The Place of Nuclear Energy in United Kingdom Power Development"; he and Mr. J. C. Duckworth, both engineers from the Operations Headquarters of the C.E.A., were joint authors of this important lecture,

Mr. Pask said that, although both the U.S.S.R. and the United States have built small reactors for generating energy, neither country expects to have commercial prototype nuclear power stations in service before the opening of the British Calder Hall station in 1956. However the main purpose of Calder Hall is the production of plutonium, and nuclear stations designed specifically for power production are unlikely to be operating before 1961. The lecturer gave some detailed figures summarizing the likely British power demand and output up to the nineteen-eighties. Even by 1965, more nuclear plant than was proposed in the Government programme, or more thermal plant using imported fossil fuel, would be needed to meet the expected load.

Next the economics of nuclear generation were considered. The Calder Hall station would cost around £300 per kilowatt of rated capacity, but succeeding British stations should cost substantially less, perhaps about £150 per kilowatt. These figures did not include the cost of the first charge of fuel elements which could conveniently be considered as capital outlay. The amortization period of a nuclear power station should be at least twenty years, and for a future 200 MW station operating at 75% load factor an annual capital charge of about 0·37d./kWh might be expected. Turning to operating costs, Mr. Pask said that the Other Works costs (about

Sir Christopher Hinton opening the first meeting of the British Nuclear Energy Conference

0·06d./kWh)—salaries, wages, stores, and maintenance—would initially be higher than for a coal-fired station, but that higher heat ratings should reverse this. On the assumption that a ton of fuel would give 3 000 MW-days before replacement and a heat-energy/electrical-energy conversion efficiency of 25%, the cost of replacement fuel would be about 0·27d./kWh, giving a gross generation cost of about 0·7d./kWh. This figure did not include any credit for the plutonium generated and the net generation cost at a 200 MW station was likely to be around 0·43d./kWh, somewhat less than at a coal-fired station.

Mr. Pask went on to survey some future possible types of reactor. The light-water-cooled and -moderated reactor should permit higher heat ratings than the gas-cooled reactor, but the high vapour pressure of water implies a 1 000-lb/inch^2 pressure vessel to achieve a temperature of even 550° F, and the dissociation of water under irradiation can cause explosive mixtures. He mentioned the homogeneous type of reactor and stressed its advantages for achieving a positive gain of fissile material, probably by using the uranium-233/thorium cycle; the existence of such a reactor (Zetr) at Harwell was announced in January, 1956.

The nuclear power programme does not allow any relaxation in the efforts to improve new coal-fired plant. It is essential that all future plant should be capable of two-shift working, with higher steam conditions and higher load factors; pumped storage can make a useful contribution towards the latter, and the economic case for it is improving.

The lecture ended with a brief survey of the impact of nuclear power on system planning. Nuclear power stations will probably be situated on estuaries or the coast where little or no coal was mined and as near as possible to major load centres; none of the early ones would be in heavily populated areas.

After a comment by Sir Christopher Hinton on the cost of coal-fired stations assumed by Mr. Pask and Mr. Duckworth, the discussion of the lecture was opened by Mr. J. Eccles. He said that the future demand for energy in Britain, on the assumption of full employment and increasing mechanization, had been estimated to be the equivalent of 400×10^6 tons of coal by 1980. For 1955 the corresponding figure was 255×10^6 tons. Of the 400 million tons, 135 might be required as oil, 120 as electricity, and 140 as gas and solid fuel. We should perhaps not mine annually more than 225×10^6 tons of coal by 1980, and therefore we should be importing a great deal more oil unless the nuclear plant programme were substantially stepped up, which would release some of the coal for conversion to oil. He suggested that we should aim at a coal equivalent of 83×10^6 tons/year by 1980 from nuclear sources, instead of the authors' figure of about 62×10^6 tons/year. But much depended on whether it would be physically possible to build stations fast enough. Mr. Eccles thought we should need about ten new nuclear stations a year from 1975 to 1980.

Mr. G. F. Kennedy, who spoke next, believed that nuclear fuel might become competitive with coal in the early nineteen-sixties, owing to the rising price of coal. In that event the nuclear power programme should be stepped up and more coal should be conserved for use in the carbonizing and gasification industries. More could be done by pumped storage and suitable tariffs to improve load factor, and research into medium-sized nuclear reactors intermediate between the gas-cooled and fast-fission types was needed.

Another speaker in the discussion was Sir Claude Gibb, who declared that industry can and must meet the kind of programme Mr. Eccles and the authors called for. He was glad to hear the lecturer debunking the idea that nuclear power provided a kind of panacea to replace hard work. Sir Claude stressed that it was imperative not to rely on supplies of oil imported from the explosive Middle East, and he also thought that the export position for reactors was not so rosy as it had seemed a year ago. He wanted to know why the authors had taken 200 MW as their limit for power-reactor rating.

After an interval for tea, and an unexpected lighting failure that seemed suggestive of the uncertainty of power supplies in the future, two further lectures were given, each being followed by a discussion. The first was on "Health and Safety in a Nuclear Power Industry" by Dr. A. C. McLean (Group Medical Officer of the Industrial Group of the U.K.A.E.A.) and Dr. W. G. Marley (of the Health Division of the A.E.R.E.). The second was by Mr. H. J. Grout (of the Reactor Engineering Division of the A.E.R.E.) on "The Use of Research Reactors in Nuclear Power Development."

The size of the audience throughout this opening meeting of the British Nuclear Energy Conference had emphasized the need for such an association, and the Chairman's remarks and the four excellent lectures with their discussions set a high standard for future meetings of the Conference. In the years ahead when nuclear engineering will become one of the most important technological pursuits of Britain, the B.N.E.C. has a signal role to play among the numerous scientists and technologists that will be engaged in it.

A report of the Inaugural Meeting of the Conference with the full text of all the lectures and discussions appears in the January issue of the *Journal of the British Nuclear Energy Conference*.

LONDON

MEASUREMENT AND RADIO SECTIONS

Electron Paths

Two papers on an electrolytic tank equipment for plotting potential, potential gradient and electron paths were presented at a joint meeting of the Measurement and Control and the Radio and Telecommunication Sections on the 15th November, 1955. The highly specialized nature of the subject attracted a small but attentive audience.

Dr. D. L. Hollway, who is at the Commonwealth Scientific and Industrial Research Organization, Sydney, was unable to read his own papers, but Dr. J. H. Westcott undertook this task and his clear presentation and easy manner made up for the absence of the author. A short review of the papers appears on page 112.

The discussion was opened by Mr. E. R. Hartill, who suggested that in a wedge-shaped tank, which was mentioned by the author, the depth of the electrolyte is least where the need for accuracy is greatest, and the shallow electrolyte introduces defocusing gradients and gives rise to variations of potential on account of differential heating. Mr. D. H. Davies was concerned lest the human element in the plotting process should adversely affect its accuracy; to avoid the meniscus present with probes near the surface he was considering the use of probes at the bottom of the tank. He did not think that the method could be readily extended to time-varying fields, as stated by the author, since the electron path is then no longer defined by the potential gradient.

Dr. G. Liebmann welcomed the author's refreshing return to a simple technique and his ingenious scheme for simulating electric and magnetic fields. He considered that the accuracy attained in electrolytic tanks was insufficient for applications to electron optics or where space charge exists. Finally he asked how the present method compared with the author's tracing-paper method, or whether he had given up the latter.

Mr. B. J. Mayo suggested that, following Musson-Genon, space charge might be allowed for by variations in the depth of the tank; he, too, stressed the difficulties in dealing satisfactorily with electron lenses.

Dr. D. Gabor was pleased that the method he had devised nearly twenty years ago had been brought up to date and had been used in new applications by the author; however, he stressed the advantages of the dynamometer wattmeter as an indicator—it was simple and insensitive to the quadrature component. When he constructed his original apparatus there were only a few uses for it: either the accuracy required was beyond its capabilities or the problem was too crude to require more than a pencil and paper.

Most of the speakers in the discussion referred to difficulties associated with the probes and their depth of immersion and several preferred a deep tank taking 180° models.

Replying to the discussion, Dr. Westcott said that an advantage in reading someone else's paper was that he could not be expected to give full answers to all the points raised, and, indeed, he wished to ask a question himself but he supposed that it would be out of order; however, he had one or two comments to make. On repeatability and the human element he had no direct evidence, but there was nothing to indicate that fatigue was a serious element in the plotting. He thought that the comment on time-varying fields was a fair one, and he agreed that the depth of the probes was a most important parameter. Finally he mentioned that the author had published a paper on the subject in the *Australian Journal of Physics* of March, 1955, in which space charge was simulated by the injection of suitable currents.

Mr. Stanesby proposed a vote of thanks to the author and to Dr. Westcott for presenting the paper. He had found the subject a stimulating and interesting combination of the activities of the two sections; it described a technique of measurement that might well become a vital tool in the development of a wide variety of electronic devices.

All About the Thermistor

According to the catalogue, a thermistor is "a resistance body with a high negative temperature-coefficient of resistance, and constitutes a valuable circuit element." Just how valuable was revealed in two papers read by Dr. C. J. Candy at a joint meeting of the Measurement and Control and the Radio and Telecommunication Sections held on the 29th November with Mr. W. Bamford in the chair. It was a small meeting, the attendance amounting to only about thirty, but for what it may have lacked in quantity, it certainly made up in quality, both by Dr. Candy's very elegant treatment of his subject, and the discussion which followed. Dr. Candy's first paper dealt with the thermistor in very-low-frequency systems, and his second gave a mathematical treatment of the response to amplitude-modulated signals. Short reviews of the papers are published on pages 114 and 115.

Dr. D. Morris, who opened the discussion, clearly indicated the interest which had been aroused by Dr. Candy's papers, and besides asking a few pertinent questions, offered some suggestions, such as the reduction of the time-constant by artificial ventilation, and the recording of performances by means of a pen recorder, the chart being driven by a synchronous motor at a very

low frequency, thus enabling the trace to be made of constant length for all the frequencies used.

It was perhaps a little surprising to find Mr. P. P. Eckersley in the list of speakers in this somewhat specialized field. While he opened in characteristic vein, however, he soon showed that he had every intention of getting down to brass tacks or, to use his own metaphor, the "therm" in "thermistor." The effect of changes in ambient temperature were his main concern.

Several other speakers offered constructive suggestions as to how to get along with this interesting device in usable form. Mr. F. C. Widdis, in particular, commented on the astonishing reproducibility of the characteristics of the thermistor, while Mr. T. Ritson remarked on its extraordinary versatility and the fact that the thermistor network is not complicated in practice, though in theory it may be. Professor A. Tustin has usually something of interest to contribute to a discussion, and his suggestion of constructing a form of ladder network with indirectly heated thermistors, for use in a feedback system, must have tickled many technical fancies.

After Dr. Candy had replied to the many points raised, Mr. H. Stanesby, representing the Radio and Telecommunication Section, moved a vote of thanks, and complimented Dr. Candy on his pioneering papers which had stimulated so much interest. J. K. W.

SUPPLY SECTION

Thermocouples and Resistance Thermometers

Members of the Supply Section who saw the announcement of a paper by D. H. Lucas and M. E. Peplow on *The Measurement of Steam Temperatures in Power Stations* may well have wondered why it was to be read at Savoy Place and not at Birdcage Walk, but those who were present on the evening of the 14th December soon found themselves on familiar ground, discussing the relative merits of thermocouples and resistance thermometers, time-constants, temperature gradients, Bessel functions, and the like. In this atmosphere of electrical technology the Supply Section could feel at home.

In presenting the paper, Mr. Lucas spoke of the difficulty he and Mr. Peplow had in deciding whether they should place the emphasis on theory or on practice. They expected to be criticized for their deficiencies by both the theorist and the practical man. The accurate measurement of steam temperatures in the region of 1000° F was of great importance from the point of view of turbine efficiency and safety of operation. Errors in measurement could occur, however, through temperature gradients existing in the steam itself, between the steam and the thermometer pocket, and between the pocket and thermometer. In addition, the thermometer might be inaccurate, or have too slow a response. The paper considered each of these possible sources of error theoretically and confirmed the conclusions by measurements made at Deptford West power station. Mr. Peplow, following Mr. Lucas, outlined the practical difficulties encountered and the methods used to overcome them. The authors' conclusions were that steam temperatures in a pipe may be considered uniformly distributed at about thirty diameters from a junction, that temperature gradients in a well-lagged pipe are negligible except near the pipe wall, that errors in temperature measurement can be made negligibly small by suitable precautions, and that the extra accuracy obtainable by immersion of the thermometer in the steam does not justify the risk involved.

Most of the discussion centred round the questions (*a*) whether the thermocouple or the resistance thermometer is to be preferred, (*b*) whether the thermometer should be in a pocket or in the steam, and (*c*) whether a relatively slow response is permissible.

Professor W. Fishwick, and Messrs. Llewellyn Young, H. S. Horsman, A. F. Brittin, F. Shakeshaft, J. McMillan, H. J. Lowe and H. R. Westaway took part in the discussion. There was strong support for the thermocouple as being more robust, if less accurate, than the resistance thermometer, and as lending itself more readily to direct immersion in the steam. A number of speakers favoured metal-to-metal contact of the thermometer with its pocket to reduce time-lag in the readings. Several speakers drew attention to the possible mechanical failure of pockets.

Mr. Peplow, in reply, held no brief for resistance thermometers. They had been used for the measurements recorded in the paper because thermocouples were difficult to calibrate accurately; properly designed resistance elements could have a smaller time-lag than thermocouples. Directly-immersed thermocouples had, however, been used by the authors.

In the course of the discussion there was one point on which all the speakers were agreed, namely the advantages of a long pocket. In the midst of the Christmas shopping season, this conclusion received general assent. C. P. H.

BIRMINGHAM

SOUTH MIDLAND CENTRE

The activities of the Centre for the 1954–55 Session were brought to an end with a successful Summer Visit in June, when Mr. A. R. Blandford, the Chairman, and Mrs. Blandford headed a party of over one hundred members and their ladies, including both Rugby and North Staffordshire Sub-Centres, on a visit to Southwell Minster, where many members were taken on a most interesting tour by the enthusiastic and knowledgeable Provost. The afternoon was spent in inspecting the drug factory of Boots Ltd. at Beeston.

The new session was opened as usual with the Annual General Meeting followed by an Address from the Chairman, Lt.-Col. H. S. Davidson, the evening concluding with a Conversazione at which some 300 members were present. Mr. T. E. Goldup addressed the meeting in his capacity as a Vice-President.

Each year a joint meeting is held by the local branches

of the three major Institutions, arranged in turn by each of them. This year it was the turn of our own Institution and a very interesting lecture was given by Commander C. G. Forsberg and Mr. G. G. MacNeice on *The Search for, and Salvage of, the Comet Aircraft near Elba.*

The Radio and Telecommunication Group had a very promising Opening Meeting in October when over a hundred members enjoyed a lecture on *Colour Television* by Mr. Jesty.

The Graduates and Students Section enjoyed a most successful Summer Visit to the Tal-y-Llyn Railway in Wales, when 80 members made the journey. The Section has been pursuing its policy of more joint meetings with fellow students, including a highly enjoyable dance with The Institutions of Civil and of Mechanical Engineers, and a joint meeting with the former for a paper on *Guided Missiles* by Mr. Stevens. R. H. P.

CARDIFF AND BRISTOL

WESTERN CENTRE

The session got away to a good start on the 10th October, 1955, when a meeting of about 100 members welcomed Mr. T. G. Dash to the chair. After thanks to Mr. A. N. Irens for his excellent services as Chairman during the past session, Mr. Dash proceeded to give his Address on *The Mining Electrical Engineer and the I.E.E.* He emphasized the increasing complexity of machinery used in modern mining, and showed slides of typical plant. In the early days South Wales pits were pioneers in the use of generating plant, and some large stations were built; now they were pioneers in coal cutting, hauling and handling equipment. He went on to survey the opportunities for young men entering the field of mining electrical work and reaching positions of trust with professional status.

In a vote of thanks Mr. J. Vaughan Harries said that the new Chairman had given members quite a lot to think about; the nation now recognized the work of the engineer, and it was essential that some of the best brains of the electrical industry should be available for mining development.

Railway Electrification

On the 14th November Mr. J. A. Broughall and Mr. K. J. Cook presented their paper on *The Electrification of the Manchester–Sheffield–Wath Lines, Eastern and London Midland Regions, British Railways*, at a well attended meeting at Bristol. Mr. W. L. Creighton, who opened the discussion, had worked with the authors, and brought out a number of interesting points. The opinion was expressed that similar projects in the future would employ single-phase alternating current with the rectifier on the train. The consequent saving in substations and cabling would be considerable. A vote of thanks proposed by Mr. F. B. Allcock was carried with acclamation.

WESTERN CENTRE SUPPLY GROUP

Not in the Time-Table

Fifty-five members and their ladies enjoyed a most interesting outing on the 1st October, when the Supply Group visited the works of the Westinghouse Brake and Signal Co. at Chippenham. After spending the morning in touring the works, the party were entertained to lunch by the company. Mr. E. K. Wood thanked them for their hospitality and Mr. W. E. Wilkins replied. A tour of the Cotswolds followed, and stops were made at Malmesbury, Westonbirt and Badminton. The Supply Group organizers have the happy knack of picking the right day—the weather was brilliant for the third successive year.

But eight members from Newport will remember the outing for another reason. Arriving at Bristol station half an hour early, they gleefully boarded a returning excursion train which was labelled "Newport, Cardiff." The engine driver, however, had ideas of his own, and the smiles gave way to consternation when the train jogged gently through Newport station and on the extra twelve miles to Cardiff. They got back all right—an hour late; but, after all, there *was* an extra hour to spare that night, since the clocks were put back for the end of Summer Time.

The Problems of Supply

At the meeting of the Supply Group at Cardiff on the 17th October, after the usual formalities and thanks to the outgoing Chairman, Mr. E. K. Wood gave his Chairman's Address on *Some Problems Arising in the Manufacture and Delivery of Equipment for the Supply Industry*. This was illustrated by slides showing heavy electrical plant being erected and tested at works, and by two films illustrating transport problems, particularly some encountered locally. Mr. C. W. Priest, proposing the vote of thanks, described the Address as one of the most interesting he had heard.

WESTERN CENTRE UTILIZATION GROUP

The session opened on the 24th October at Bristol when the retiring Chairman, Mr. T. Gill, handed over his office to Mr. W. H. Small. After expressing thanks to Mr. Gill for the excellent way in which he had carried out his duties, Mr. Small extended a hearty welcome to the Section Chairman, Mr. D. B. Hogg, who said how happy he was to be in "Bristol, your ancient and beautiful city." Mr. Hogg then repeated the Chairman's Address which he had given in London earlier in the month. At the conclusion a vote of thanks was proposed by Mr. J. M. Knowlson. B. C. R.

NOTTINGHAM

EAST MIDLAND CENTRE

The Faraday Lecture

Coal Mining Electrically made its third appearance in the provinces at the Albert Hall, Nottingham, on the 15th December, 1955. This Faraday Lecture, on a topic of wide local interest, was warmly received by the audience, both from the manner of its smooth delivery by Mr. Metcalf and the stagecraft of his team of demonstrators.

The purpose of the Faraday Lecture was explained, and the lecturer introduced, by Mr. F. R. C. Roberts, Chairman of the East Midland Centre; he deputized for the Lord Mayor of Nottingham, who was then recovering from a recent illness.

The audience showed a keen appreciation of the historical background of the mining industry, and the benefits it has derived from Faraday's early studies. Modern electrical equipment has evolved from his work on electromagnetic induction, and safety in the mines had a beginning in his association with the Davy lamp and his experiments on fire-damp.

Among the distinguished guests attending the lecture were Mr. R. Ringham, Mr. W. Unsworth, Mr. W. L. Miron, Mr. N. R. Smith, Mr. H. S. Barnett, Mr. C. S. Jenkins, Dr. N. M. Potter, Mr. W. B. Brown and Mr. C. D. Wilkinson, all of whom represented the mining industry in the area; Mr. L. F. Jeffrey, Mr. J. D. Pierce, Mr. J. Mould, Mr. M. Tattersfield, Mr. J. P. Tucker and Mr. R. G. Hooker, representatives of the electrical industry; Mr. J. Edward Mason, Professor J. E. Parton, Professor J. A. Pope, Dr. H. L. Haslegrave, Professor F. B. Hinsley, Mr. A. W. Hirst and Mr. G. R. Davison, representatives of the local education authorities and institutions.

A vote of thanks to Mr. Metcalf was given by Dr. H. L. Haslegrave, Senior Vice-Chairman of the Centre, who also referred to the many people who had helped to make the evening a success.

An afternoon "performance" was received with even greater enthusiasm by some 1 500 pupils drawn from schools in Nottingham and the surrounding district.

From the reaction of the audience to the afternoon lecture it would appear that amongst the high-lights were the explosive demonstrations of methane, the cage-winding operator who earned an L-plate, and the fumbler who aptly demonstrated the immunity of mine-lighting equipment to rough treatment.

A vote of thanks was given on behalf of the audience and the local education authority by Mr. W. G. Jackson, Assistant Director of Education.

W. A.

READING

DISTRICT MEETING

Semi-Conductor Physics

Dr. T. E. Allibone presided at the meeting on the 28th November, 1955, for a talk on *The Physics of Transistors* by Dr. E. Billig.

The four fundamental types of solids, i.e. molecular, ionic, metallic and covalent crystals, were discussed by means of the electron band theory of solids. The covalent crystals in particular are of great interest as semi-conductors, comprising especially the elements in Group IV of the Periodic Table, and the compounds of an element in Group III with one in Group V.

The electronic band structure of a solid is the equivalent of the scheme of discrete energy levels in a single atom or a simple molecule. The feature of main importance for semi-conductors is the mechanism of two-band conduction in these covalent crystals, i.e. the possibility of electrons moving independently in two separate energy bands. In the *conduction band*, they move as ordinary electrons (with negative charge), but in the *valency band* they move as *holes* as if they carried a positive charge. Substitution of a small number of atoms in a germanium crystal, for instance by atoms of arsenic, causes the introduction of additional electronic charges into the lattice, i.e. makes the semi-conductor *n*-type, whilst substitution by trivalent gallium, for instance, introduces additional holes into the crystal and makes it *p*-type. Judicious "doping" with such specific *donor* or *acceptor* impurities makes it possible to control the electronic conductivity of these semi-conducting crystals to any required value. By doping two adjacent parts of one coherent crystal with minute quantities of acceptors and donors respectively, a perfect *p–n* junction can be prepared. Subsequent diffusion of mobile electrons and holes away from the junction produces a space-charge region—the gallium and arsenic ions left in the germanium lattice—having a large dipole moment and producing a strong electric field.

The existence of this dipole layer accounts for certain effects observed at such junctions. For instance, a photo-voltaic voltage is generated by irradiating a junction with visible light, or a thermo-electric voltage by heating it above the ambient temperature. Electron-hole pairs are excited either optically or thermally, and are then separated by the electric field and eventually accumulate on each side of the junction. On the other hand, the application of an electrical potential difference across the terminals of a junction will produce a flow of current whose magnitude depends primarily on the polarity of the applied voltage. Electrons and holes can be driven across the junction, i.e. large currents can pass, only if the polarity of the additional electric field is such as to overcome the internal field. With opposite polarity, no current will flow. A *p–n* junction thus has ideal rectifying characteristics.

With the junction biased in the blocking direction, carriers can be excited and current can be made to flow, by irradiating the junction region with visible light. Such a *photo-diode*, or *photo-transistor*, is thus an efficient amplifying device, for a weak optical signal can be made to cause the flow of current in a high-impedance circuit. Similar control can be exerted by purely electrical means in a transistor which has additional carriers injected from a low-impedance emitter junction across a

negatively biased collector junction into a circuit of high impedance, where they then constitute a flow of higher-power current.

The lecture was well illustrated by a number of models and experiments, and a film showing the practical aspects of the work involved in semi-conductor technology, such as zone refining and crystal growing, concluded the meeting.

Dr. A. G. Beverstock expressed the thanks of the members to Dr. Billig, particularly for the trouble he had taken in his demonstrations. H. B.

STAFFORDSHIRE

NORTH STAFFORDSHIRE SUB-CENTRE

A joint meeting with the local centre of The Institution of Post Office Electrical Engineers was held at the G.P.O. Central Training School, Stone, on the 15th November, 1955. Mr. H. R. Harbottle welcomed the members of our own Institution, and in reply Dr. E. R. Patrick said that the joint meeting was becoming one of the events of the session. He said that as Mr. R. W. Palmer was on his home ground he needed no formal introduction, and he was sure that everyone present was pleased that Mr. Palmer had been awarded the 1954–55 Llewellyn B. Atkinson Premium for his paper on *Maintenance Principles for Automatic Telephone Exchange Plant*, which Dr. Patrick then invited Mr. Palmer to read.

A lively discussion was opened by Mr. H. Baker, who considered that the new philosophy propounded by Mr. Palmer was justified, especially for the proposed electronic exchanges, and many speakers emphasized that routine adjustments on automatic exchanges were often followed by a crop of faults.

Mr. J. H. Pirie proposed the vote of thanks. He remarked on the high standard of papers presented at these joint meetings, saying that the present paper had been even more stimulating than usual. He also congratulated Mr. Palmer on his able and witty replies to the discussion.

Finally Dr. Patrick thanked Mr. Harbottle for the use of the Post Office facilities, and Mr. Harbottle replied that Duncan Hall was something of a colony and required other people to come in from time to time to keep the balance. He always looked forward to these joint meetings.

The Annual Dance

The Annual Dance held at the Crown Hotel, Stone, on the 18th November, again proved to be a very enjoyable affair. The fog which had prevailed for a few days cleared away in good time to enable the 150 members and guests to travel without difficulty. A varied programme of dances was arranged and the proceedings were considerably enlivened at times by the ingenious schemes introduced by the Master of Ceremonies, Mr. W. E. Darby, to make it more difficult to win the prizes. Before the close, Mrs. E. R. Patrick gracefully presented the prizes and the Chairman, Dr. Patrick, thanked all who had worked to make the evening such a success.

Faraday Lecture at Hanley

The Sub-Centre was greatly privileged this year to hear the Faraday Lecture for the first time, when it was given in the Victoria Hall, Hanley, on the 7th December. As coal mining is one of the major industries in this area, the active support of the local staff of the National Coal Board was sought at an early stage, and Mr. T. Storrs, Area Chief Electrical Engineer, was invited to join the Sub-Committee formed to make the arrangements. The advice and assistance of the Committee and officials of the South Midland Centre were freely given, and special thanks are due to Mr. A. R. Blandford, then Chairman, for his support and his detailed suggestions which proved to be invaluable.

Dr. E. R. Patrick, presiding, briefly explained the purpose of the Faraday Lectures, and the lecturer was introduced by Mr. Rowland Bennett.

It was very gratifying to find the hall filled almost to capacity and an audience of about 1 750 were deeply interested in Mr. Metcalf's lecture, which was profusely illustrated by films and demonstrations of equipment and apparatus employed in *Coal Mining Electrically*. Mr. Metcalf showed how Faraday's discovery of electromagnetic induction had

Photograph by courtesy of the *Evening Sentinel*

A preview of apparatus for the Faraday Lecture at Hanley

From left to right: Mr. W. E. Darby, Mr. R. Hill, Mr. J. P. Oliver, Mr. J. L. Hewitt, Mr. E. Bolton, Mr. L. Goodall, Mr. H. McCartney, Mr. A. R. Buttrey, Mr. T. Storrs and, seated, Dr. E. R. Patrick.

completely transformed the mining industry. He dealt with the application of electrical energy to lighting and power, medical services, safety, communications and signalling, and with the measurements involved in efficient production.

Mr. H. A. P. Caddell proposed votes of thanks to the lecturer, to Mr. Strachan and the other engineers who had staged the demonstrations, and to the City of Stoke-on-Trent for the use of the hall and for receiving the lecture so splendidly. Alderman A. E. Bennett, deputizing for the Lord Mayor who was in London, responded by expressing appreciation that Stoke-on-Trent had been chosen as one of the places to have the Faraday lecture this year. L. G.

YORKSHIRE

NORTH MIDLAND CENTRE

Cautionary Speeches

The Annual Dinner of the Centre was held on the 22nd November, 1955, at the Queen's Hotel, Leeds, and the Lord Mayor of Leeds, Alderman Sir James Croysdale, proposed the toast of The Institution.

In his reply Sir John Hacking, who as a Past-President was representing the Council, forecast that the electrical supply industry will go through a difficult time owing to the coal shortage. Oil was more costly, but was having to be used to an increasing extent. In the next ten years, however, from one to one-and-a-half million tons of coal per annum would be saved by the use of atomic energy. Britain's precedence in this field was a dire necessity.

He went on to commend Mr. J. G. Craven, the local Secretary of the Benevolent Fund, for his outstanding work.

Mr. F. Barrell, the North Midland Centre Chairman, in proposing the toast of "Our Guests," said that he was gratified to see Sir James Croysdale, and that he was also especially pleased to see Sir John Hacking, whose work on the unification of the Institutions might perhaps lead to the higher status of engineers. He went on to welcome all the guests, and coupled the toast with the name of Judge D. O. McKee, who replied in a brilliantly witty speech, thanking the North Midland Centre for their hospitality and, among some anecdotes, quoting Hilaire Belloc:

> A smell of burning fills the startled air—
> The Electrician is no longer there!

Canon C. B. Sampson, seconding the reply for the guests, was pleased to reassure members that the Church is not wedded to the "gas" industry, went on in more serious vein to urge the enormous importance of encouraging young men to teach science. He said that power is vital both to the electrical industry and the Church, which exercises moral power to control the forces of nature; the Church and industry must come into closer partnership.

A very pleasant evening ended with a reunion of members.

Circuit-Making

At the third Ordinary Meeting held on the 6th December, the Chairman, Mr. F. Barrell, welcomed one new Corporate Member and went on to introduce the speakers, Mr. G. F. Peirson and Mr. A. H. Pollard, who presented their paper *Automatic Circuit Reclosers*. Mr. Peirson, who read the paper, charmed the audience with his easy manner and held their interest throughout his discourse. He projected an excellent colour-film which was made by himself. The discussion was opened by Mr. J. D. Nicholson, who was followed by eleven other speakers, and showed the extreme interest which this paper provided for members, who asked questions on very many aspects of the subject. Mr. Pollard, in opening the reply to the discussion, had much to say in support of the stability of slow-melting fuses, which had come in for a certain amount of criticism. Those present were fully in accord when the Chairman proposed a vote of thanks.

Export or Die

At the fourth Ordinary Meeting, held on the 3rd January under the Chairmanship of Mr. F. Barrell, Mr. G. L. E. Metz presented his paper entitled *The Electrical Engineering Industry in the Post-War Economy—II*. This proved to be a most interesting exposition, dealing with every aspect of world trading, from the philosophical and near-political to the statistical and economical. Mr. Metz clearly considers that The Institution should play a more virile role in the matter of economics and not run along with blinkers on.

This paper triggered off a remarkable response from members, who, led by Mr. J. R. Rylands, gave a series of short lectures. After ten speakers had joined in, the Chairman closed the discussion with the meeting still simmering. The author replied in an interesting and unusual manner by filling in the background and indicating the special and personal reasons for his interest in this subject. A hearty vote of thanks, ably proposed by Mr. Barrell, ended the proceedings.

NORTH MIDLAND UTILIZATION GROUP

Rotation Control

The second meeting of the Utilization Group was held on the 22nd November under the able Chairmanship of Mr. J. C. W. Wilkinson. Two short papers were presented: first, *The Dynamic Braking of Induction Motors* by D. Harrison, and, secondly, *Timing the Operation of Control Systems Associated with Rotating Equipment*, by C. Cuthbert and D. A. Picken, which was read by Mr. Picken. Most contributors to the discussion that was

very ably opened by Mr. A. F. Carter seemed to have more to say about electromagnetic braking, which is dealt with fully in the second paper, than about dynamic braking; this was probably due to limited experience in the latter field. However Mr. Carter reported very satisfactory performance with dynamic braking in the sphere of machinery for wrapping. In proposing a vote of thanks Mr. Wilkinson said that the discussion had ranged from rolling-mills to mine-winders, and from margarine to motor-cars.

GRADUATES AND STUDENTS SECTION

Chairman's Address

The Opening Meeting on the 27th September was the occasion of the incoming Chairman's Address. Mr. H. J. Towse chose as his subject *Traction Control Gear Design*. Mr. J. Leeson in handing over the chair to Mr. Towse also presented him with a copy of *The History of The Institution*.

Down to Earth

On the 11th October Mr. J. R. Bennett, the Chairman of the Sheffield Graduates and Students Section, read his paper *Earth Currents* before an enthusiastic audience at Bradford.

DISTRICT MEETINGS

The first District meeting of the session at Hull was held on the 20th October when, with the convener, Mr. W. S. Milner in the chair, members welcomed Capt. R. G. Swallow to give a lecture on *Radio Aids to Marine Navigation*, which described pulsed centimetric radar and low-frequency time-difference chain transmissions for navigation at sea. An interesting discussion was opened by Mr. F. Hilton and supported by ten other speakers, and a vote of thanks, ably proposed by Mr. K. E. Kerridge, was carried with acclamation.

At the second District Meeting on the 8th December nearly 60 members and guests were present when Mr. Milner introduced the speaker, Mr. P. W. Mummery, who gave a lecture on *The Production of Economic Nuclear Power*. This outlined the basic principles of nuclear fission and its application to controlled power production. A comparision was made between the costs of production of electrical energy from coal-fired and that from nuclear-reactor stations and the value of the fissile materials created was shown to be an important factor in assessing the true cost per kilowatt-hour.

A lively discussion followed, in which the subject ranged from economics to matters of heat exchange, and when Mr. J. Lawton, a visitor from the Centre Committee, proposed a vote of thanks, it was enthusiastically supported by all present. J. L.

CORRESPONDENCE

From PROFESSOR G. F. NICHOLSON, MEMBER

ARE ENGINEERS BROAD ENOUGH?

During an informal discussion held at The Institution on the 14th November, 1955, Dr. P. Dunsheath spoke about the importance of an engineer "looking over the hedge" at work in neighbouring fields. There are, of course, two parts to this process, the actual looking over the hedge and the invitation from one's neighbour to do so.

When a new branch of science or technology is being developed, the Greek and English symbols with special connotations, and the jargon used by the initiated, present the appearance of not so much an invitation as a regrettable heightening of the hedge, which may well prevent potentially useful discussions from taking place across it.

May I make a suggestion in a specific context, which might be of value if more generally applied when new advances are being made?

This autumn there is to be a Convention on Ferrites. Would it be possible to arrange that, at least a fortnight before this event, an integrating paper should be presented by someone who has mastered the physics of the subject sufficiently to talk about it lucidly to non-specialists? Such a paper should attract all who desire to remain broadly up to date, and might encourage some to attend the Convention who would normally consider its matter to be outside their field and likely to be unintelligible. In this way a greater exchange of ideas between workers in different fields might be promoted, and engineers would find it easier to remain educated.

[Professor Nicholson's suggestion about the forthcoming Convention on Ferrites has been considered by the Radio and Telecommunication Section Committee. They agree with the importance of the general problem outlined in Professor Nicholson's letter, but they do not consider that the reading of an integrating paper on Ferrites before the Convention is practicable in the light of existing commitments, which include an introductory lecture and an integrating paper at the start of each of the specialized sessions in the Convention. A paper of this kind, by D. Polder, was published in the *Proceedings* in 1950 (**97**, Part II, p. 246). The Committee have however proposed that a brief article in the *Journal* giving an introduction to the Convention would be helpful, and it is hoped that such an article will be published later this year.]

Professor Nicholson is Professor of Electrical Engineering at the Royal Naval College, Greenwich.

Supply Section—Chairman's Address

A summary of the Chairman's Address delivered by Mr. L. Drucquer, Member, to the Supply Section on the 26th October, 1955. A long abstract of the Address is published in this month's issue of the Proceedings, Part A.

NEARLY TWO CENTURIES AGO THE INDUSTRIAL REVOLUTION first focused attention on the importance of coal, but it is only during the last half-century that, as a direct result of Michael Faraday's earlier researches into electromagnetic induction, electricity has become universally accepted.

The electrical manufacturing industry became established by the beginning of this century and in the last fifty years it has continuously progressed at an ever increasing rate; in 1954 it employed nearly 700 000 people, who produced plant and apparatus to a total value of approximately £750 million.

In the three major branches of the heavy manufacturing industry which affect supply, i.e. generation, transformation and control, the rise in electrical rating and efficiency of the plant manufactured has, over the last few years, greatly accelerated.

The average size of turbo-generator installed by the C.E.A. in 1954 was about 50 MW; this average figure will, by 1962, have risen to 140 MW. Units rated at 300–400 MW, operating under steam conditions of the order of 4 500 lb/in.^{2}, 1 100° F, are being contemplated. Larger sets, coupled with new approaches to power station layouts, have resulted in a considerable reduction in volume per kilowatt of installed capacity.

Transformer design has kept pace with the demand for higher ratings, and transformers rated at 300 MVA are now available. Considerable progress has been made in the evolution and application of core steels, and the latest cold-rolled oriented silicon steel permits a smaller core section for given core loss, with resultant lower copper loss and reduced volume.

The switchgear engineer has met the challenge of increased breaking capacity, and circuit-breakers having a rating of 7 500 MVA at 275 kV are in service. The ultimate goal of a total break time of three cycles is now being approached, whilst over the last twenty-five years the volume per kilovolt-ampere has been more than halved.

In the field of rectification, the development of contact rectifiers and the more recent germanium power rectifiers, which are now being built for ratings of over 2 300 kW, has significantly increased the efficiency of rectification, particularly at low direct voltages such as the electrochemical industry uses, and has reduced materially the required volume per kilowatt.

With the ever increasing and apparently insatiable rise of electrical demand, the gap between the fuel required and that which can be economically supplied is increasing, whilst the total available fossil fuels are rapidly diminishing and may well have become exhausted within the next century.

The advent of electrical energy produced from nuclear-fission stations is of vital importance and the bold Government programme is not before its time. Nuclear-fission stations may be producing 25% of this country's energy demand within fifteen years, and the prospects being opened up by nuclear research are almost limitless.

In the solution of its problems so far, the electrical industry has overcome its material shortages but continued progress in the future is hampered by a shortage of human brains. The probable output from the universities would appear to be insufficient to meet the present-day requirement and the growing demand of the future. As a result, the electrical industry is evolving its own long-range solution in the shape of sandwich courses which are operated in close collaboration with the education authorities; these are designed to reach a pass-degree standard in a period of five years.

The electrical age is still to come, with its challenge to the future electrical engineer, and this lays upon him the heavy responsibility for seeing that the results of future research are directed towards the salvation of mankind, not its ultimate destruction.

Electrical Engineering outside the Electrical Industry

A summary of the Chairman's Address delivered by Mr. D. B. Hogg, M.B.E., T.D., Member, to the Utilization Section on the 13th October, 1955. A long abstract of the Address is published in this month's issue of the Proceedings, Part A.

FOR THE PURPOSE OF THIS ADDRESS, I HAVE DIVIDED THE industries employing electrical men into three groups—namely electrical supply, manufacture of electrical equipment, with which is included consulting and contracting and lastly user industries who are customers of the first two groups.

An examination of the *Ministry of Labour Gazette* shows that there are at least forty-five trades or industries which have units large enough to employ one or more professional electrical engineers. Some units are so large that they employ many, doing their own consulting work and design layout, and building their own factories.

From very scanty data, I estimate that there may be 10 000 electrical engineers employed in user industries

and my Address about them has been given in the hope of encouraging young men considering a career in electrical engineering to explore this field.

Opportunities

The main stream of electrical jobs flows in the first two groups of industries, and those who wish to specialize, or who do not object to working out their lives in a narrow field, may prefer to enter and stay in these concerns. However, in the user industries the young man has more chance of reaching the higher posts quickly because he has more opportunities to climb, and by different routes. These user industries may employ civil and mechanical engineers, chemists, physicists and other scientists. The electrical man who is able and keen can get promotion by becoming, for instance, a plant manager, work study officer, or salesman, and in any event he gains greatly by rubbing shoulders with men having other training and outlooks.

Some of the larger concerns have large laboratories, and four examples are given in the Address where the causes of damage to equipment and cures found were discovered in the laboratory instead of by the older, less certain and more expensive method of trial and error. It is concluded that engineers in such industries can become all-rounders and reach the highest positions more quickly.

Responsibilities

Sir Ewart Smith is quoted as having said, "Responsibility is taken and not given." Too many engineers wait to be given responsibility and too many grumble because their pet schemes are turned down by non-technical directors, assuming that because they are engineers they have no need, as lesser men have, to prepare proper reports and give adequate reasons showing the economic case for spending money. It is suggested that when a man takes the responsibility of advising his principals to spend money, he should at least work out alternative schemes, then prepare a report in simple language showing he has done his job properly and give the reasons for his advice.

One of the greatest of his responsibilities is to get the best out of his fellow engineers and the men working for him, by studying their thinking processes and explaining the "wherefore" to those less well equipped. He then is worth much to his employers and will have little Union trouble.

On the technical side, he is responsible to see that his planning ensures that proper safety precautions are taken in the design, operation and maintenance of the electrical gear; that it is suitable for any corrosive, explosive hazard, high pressure and temperature conditions likely to be met; that all legal and other regulations are complied with. He must plan maintenance well ahead and order spares in advance, steering the difficult course between a store over-stocked with expensive items "just in case" and having an angry manager on his hands because an unordered vital spare with a long delivery period is holding up production. He should educate his management that shutting down plant in sections at planned intervals is cheaper than uncovenanted breakdowns with consequent great loss of output.

Recruitment

In my young days, most user industries got their engineers from the manufacturing or contracting industries and occasionally from supply authorities. These men had usually served an apprenticeship, attended technical colleges for part-time instruction, and had often obtained Corporate Membership of The Institution.

The proportion of university graduates has been rising since the 1914–18 War, and experience shows that these men, on the whole, are better equipped and consequently rise faster to better jobs. Nevertheless, the experienced man, who has come up the hard way, is still a very valuable asset, and such experience still has a high market value, provided the man has other good qualities as well.

Electron Path Tracing

A short review of two Measurement and Control Section papers (Nos. 1837 and 1838) entitled "An Electrolytic-Tank Equipment for the Determination of Electron Trajectories, Potential and Gradient," and "A Method of Tracing Trajectories in Crossed Electric and Magnetic Fields," by D. L. Hollway, B.E.E., M.Eng.Sc., D.Sc. (Eng.). The papers were published separately in May, 1955, and they will be republished in Part B of the Proceedings.

IN ELECTRONIC DESIGN IT IS OFTEN NECESSARY TO DEVISE AN electrode system which will constrain charged particles to move in certain desired trajectories. Since such problems usually cannot be solved by direct calculation, the best approach is often to combine calculation with a process of trial and error, the time taken to reach the result depending on the speed and accuracy of the method used to solve the electron trajectories. It has been found that a path computer based on the electrolytic tank analogue has advantages in speed, accuracy and convenience over alternative methods.

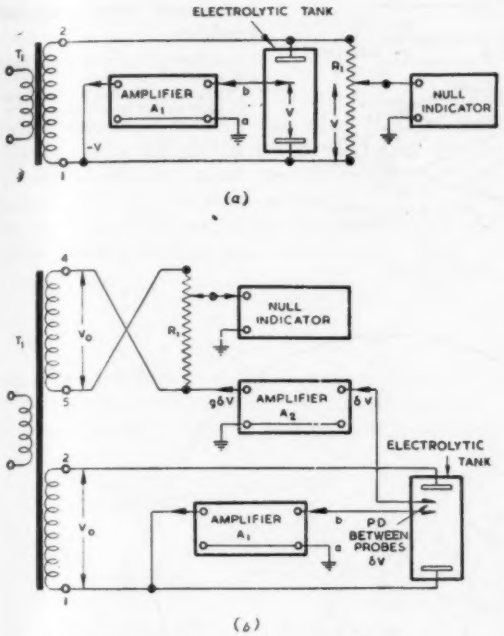
The electrolytic tank and path computer described in the first paper is designed on general-purpose lines to measure potential and potential gradient, to mark equipotential lines and to trace electron trajectories. The electron path tracer is based on a principle originally described by Gabor.*

The tank has a working area of 120 cm × 60 cm and is 30 cm deep. A Perspex floor is mounted on a frame inside the tank, designed so that it may be set at any desired level or inclination. By setting the floor horizontal two-dimensional problems may be solved; by

* GABOR, D.: "Mechanical Tracer for Electron Trajectories," *Nature*, 1937, 139, p. 373.

inclining the floor a wedge of water may be isolated to represent a system having axial symmetry.

The circuit used for potential measurement is shown in a simplified form in Fig. 1(*a*). The potentials of the electrodes in the tank are provided by taps on the secondary winding 1–2 of transformer T_1, across which a two-dial potentiometer R_1 of the Kelvin–Varley type is also connected. The measuring probe is connected to the input of a high-gain phase-reversing amplifier A_1, the output of which is connected to terminal 1 of the same secondary winding. This negative-feedback loop operates to bring the liquid surrounding the probe exactly to earth potential. Thus, when the potentiometer is adjusted so that a null point is indicated, the p.d. between the probe and terminal 1 may be read from the dials of R_1. For tracing equipotentials, R_1 is set to the desired values and the contours are recorded semi-automatically by an electromagnetic pen.



1 *Basic circuits for the measurement of potential and potential gradient*

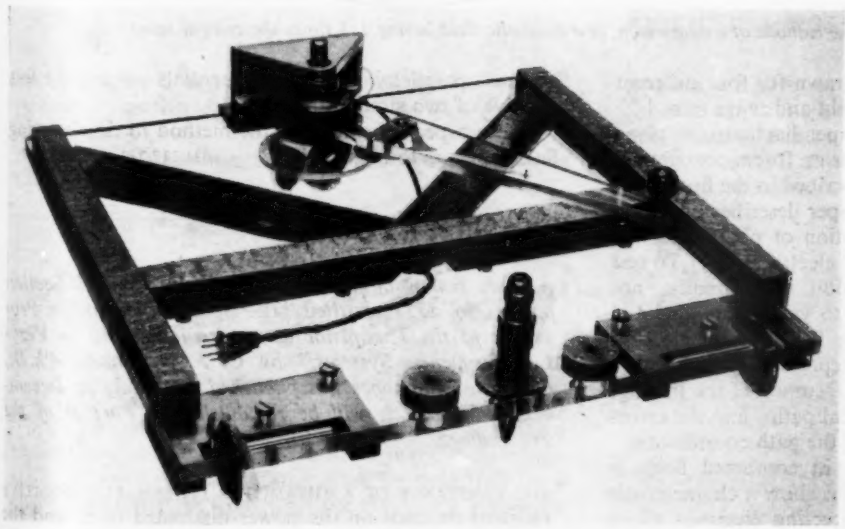
(*a*) Potential. (*b*) Potential gradient.

Potential gradient is measured by a second (or gradient) probe spaced 2·5 mm from the first (or potential) probe and the circuit is changed to that shown in Fig. 1(*b*) by a switch. The potential across R_1 is now provided by the winding 4–5 of T_1, which is identical with winding 1–2. As before, the amplifier A_1 operates to bring the potential probe to earth so that the gradient component is proportional to the p.d. between the gradient probe and earth. This signal is amplified by A_2 and measured on the potentiometer R_1.

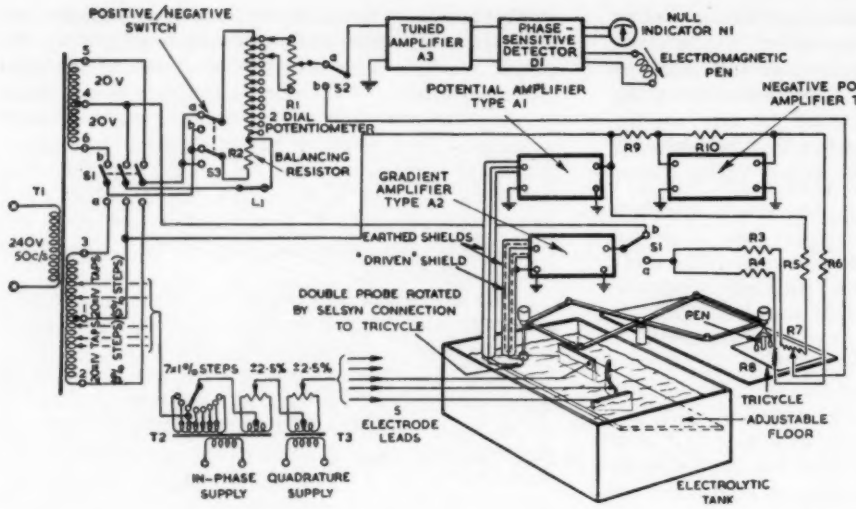
The method of path tracing depends upon correct determination of the curvature of the path at all points. The paths are drawn by a pen fixed to a three-wheeled carriage or tricycle (Fig. 2) in a position corresponding to that of the potential probe in the electrolyte. In pure electric fields the curvature is proportional to the ratio of two potentials, one representing the component of field gradient perpendicular to the path and the second the electron energy. These potentials are derived from the tank and transmitted by the gradient and potential amplifiers to the tricycle to control the curvature.

The circuit used in switching the equipment to the different functions is shown diagrammatically in Fig. 3.

The errors introduced by the electronic circuits do not appreciably reduce the accuracy of the tank and probe mechanism. The accuracy of the path tracers has been measured by drawing parabolas in a test cell providing a

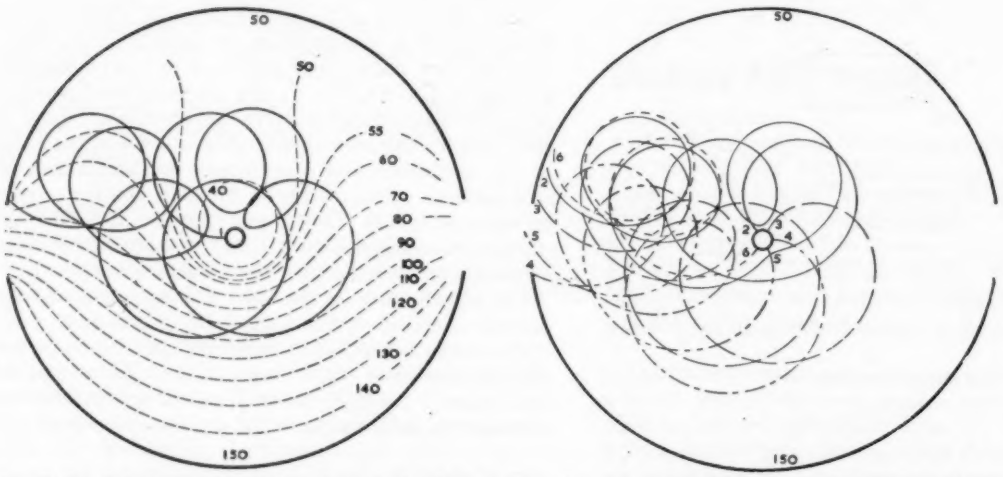


2 *Tricycle*



3 *Layout of the electrolytic-tank equipment showing the electrode supply transformers and amplifiers*

For different functions the circuits are switched as follows:
Potential measurement. S_1 and S_2 are set in position *a*.
Gradient measurement. S_1 is set to *b*, S_2 to *a*.
Electron trajectory tracing. S_1 set to *a*, S_2 to *b*.



4 *Paths of electrons emitted from the cathode of a magnetron, in a magnetic field having 1·5 times the critical value*

uniform field. In typical paths drawn for four different trajectory angles the errors in height and range were 1%.

When a magnetic field exists perpendicular to the plane of the path the curvature results from forces contributed by both fields and the method described in the first paper is not applicable. The second paper describes a general method of extending the application of path tracers to problems including magnetic and electric fields. To test the method experimentally, additional circuits, not shown in Fig. 3, were arranged to generate a potential proportional to both the magnetic field and the electron velocity, and to add it to that representing the electric field in the existing tracer. The accuracy of the tracings was checked by drawing trochoidal paths, and the errors were found to be less than 1% of the path co-ordinates.

An example of paths traced in combined fields is reproduced in Fig. 4. These paths show a characteristic effect of a magnetic field in directing electrons along channels parallel with the equipotentials toward the less positive of two similar anodes.

The prospect of extending the method to time-varying fields appears to be promising. 621.317.729 : 621.317.329

Thermistors

A short review of a Measurement and Control Section paper (No. 1751) entitled "The Specification of the Properties of the Thermistor as a Circuit-Element in Very-Low-Frequency Systems," by C. J. N. Candy, Ph.D., Graduate. The paper was published separately in December, 1954, and it will be republished in Part B of the Proceedings.

THE RESISTANCE OF A THERMISTOR (THERMALLY SENSITIVE resistor) depends on the power dissipated in it, and the

variations in the resistance lag the power by an amount determined by the thermal properties of the thermistor. It follows that the voltage across a thermistor depends on the current flowing in it and upon the rate of change of that current.

A thermistor which is polarized by a steady direct current has an impedance to small-amplitude alternating currents given by

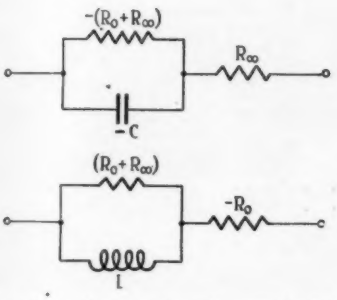
$$Z_T = R_\infty - \frac{R_0 + R_\infty}{1 + j\omega\tau} \quad . \quad . \quad . \quad . \quad (1)$$

At relatively high frequencies (greater than 10 c/s) the thermistor acts as a pure resistance, R_∞, and this is the absolute value of the thermistor resistance for the particular polarizing current. At low frequencies the impedance tends to a negative resistance, $-R_0$, equal to the slope of the voltage/current characteristic of the thermistor. When the frequency is given by

$$\omega = \frac{1}{\tau}\sqrt{\frac{R_0}{R_\infty}}$$

the thermistor acts as a pure reactance $\sqrt{(R_0 R_\infty)}$, where τ is the thermal time-constant of the thermistor.

Two equivalent circuits of a polarized thermistor are



1 *Equivalent circuits of a polarized thermistor*

shown in Fig. 1 and some typical values of the circuit parameters are listed in the table.

Impedance of Thermistor A1522/100 with various Polarizing Currents

	R_∞	R_0	L	C
mA	ohms	ohms	H	μF
13	300	130	600	3 250
8	650	350	1 400	1 400
5	1 300	625	2 700	720
1	12 200	4 000	22 500	86

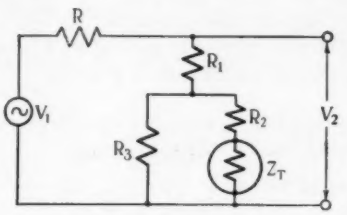
Fig. 2 shows a circuit which may be used to obtain a phase advance of a voltage. In order that the distortion shall be small, the thermistor must be polarized by a current greater than four times the maximum amplitude of the signal current. This circuit has a time-constant given by

$$\tau_g = \tau\frac{(R_X + R_\infty)}{(R_X - R_0)} \quad . \quad . \quad . \quad . \quad (2)$$

where

$$R_X = R_2 + \frac{R_3(R_1 + R)}{R + R_1 + R_3} \quad . \quad . \quad . \quad (3)$$

This is the resistance presented to the thermistor. The value of this time-constant may be adjusted by varying R_X; when R_X approaches R_0 the circuit becomes unstable.



2 *General phase-advance network*

When a high-frequency current (50 c/s) flows in a thermistor the resistance assumes the steady value it would have if a direct current equal to the r.m.s. value of the alternating current were flowing in it. The form of the thermistor impedance is a consequence of the variation of resistance with the applied power. It is concluded that the impedance presented to the envelope of a modulated current is given Z_T in eqn. (1). Circuits designed for use with direct currents may be employed in systems where modulated signals are used: the thermistor must now be polarized by steady alternating current in phase with the carrier.

621.316.86 : 621.3.011.21 : 621.3.012.8

Amplitude-Modulated Signals

A short review of a Measurement and Control Section paper (No. 1772) entitled "A Vector Method for Amplitude-Modulated Signals," by C. J. N. Candy, B.Sc., Ph.D., Graduate. The paper was published separately in January, 1955, and it will be republished in Part B of the Proceedings.

THE PAPER DESCRIBES A METHOD FOR REPRESENTING amplitude-modulated alternating quantities by the real part of the product of two rotating vectors.

The familiar j-notation used in the analysis of alternating-current circuits is based on the representation of sinusoidal functions by the real part of a vector, thus:

$$\cos \omega t = \mathscr{R}\varepsilon^{j\omega t} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In order to represent an amplitude-modulated quantity by a vector, two different operators, j_m and j_c, are defined;

these are similar to j in that $j_m^2 = -1 = j_c^2$. Functions of j_m and j_c behave like ordinary complex numbers. For example,

$$\mathscr{R}\varepsilon^{(j_m\omega_m + j_c\omega_c)t} = \mathscr{R}\left[\cos\omega_m t + j_m \sin\omega_m t\right]\left[\cos\omega_c t + j_c \sin\omega_c t\right] = \cos\omega_m t \cos\omega_c t \quad . \quad (2)$$

An amplitude-modulated voltage or current may be represented by the real part of a vector as in eqn. (2); it is readily seen that the impedance of an inductance and a capacitance to such a voltage is given by $(j_m\omega_m + j_c\omega_c)L$ and $1/[(j_m\omega_m + j_c\omega_c)C]$ respectively. An example will illustrate the method of circuit analysis. A voltage $v = \hat{V}\cos\omega_m t \cos\omega_c t$ may be represented by the vector $\boldsymbol{V} = \hat{V}\varepsilon^{(j_m\omega_m + j_c\omega_c)t}$ and if this voltage is applied to a pure inductance L, the vector for the current is given by

$$\boldsymbol{I} = \frac{\boldsymbol{V}}{(j_m\omega_m + j_c\omega_c)L} \quad . \quad . \quad . \quad . \quad (3)$$

and the instantaneous current is

$$i = \mathscr{R}\boldsymbol{I} = \mathscr{R}\frac{\hat{V}}{(j_m\omega_m + j_c\omega_c)L}\varepsilon^{(j_m\omega_m + j_c\omega_c)t} \quad . \quad (4)$$

Multiplying both the numerator and denominator by $(j_m\omega_m - j_c\omega_c)$ gives

$$i = \frac{\hat{V}(\omega_m \sin\omega_m t \cos\omega_c t - \omega_c \cos\omega_m t \sin\omega_c t)}{(\omega_m^2 - \omega_c^2)L} \quad (5)$$

A complementary operational method is described in the paper; this is based on two differential operators D_m and D_c defined by the equations

$$D_m(mc) = \frac{dm}{dt}c \quad \text{and} \quad D_c(mc) = m\frac{dc}{dt} \quad . \quad (6)$$

When the modulation m and the carrier c are sinusoidal functions of time, D and D_c become $j_m\omega_m$ and $j_c\omega_c$ respectively.

These operators aid in the calculation of the response of circuits to signals which consist of a carrier whose amplitude is modulated in accordance with any general function of time.

621.376.2 : 621.3.012.1

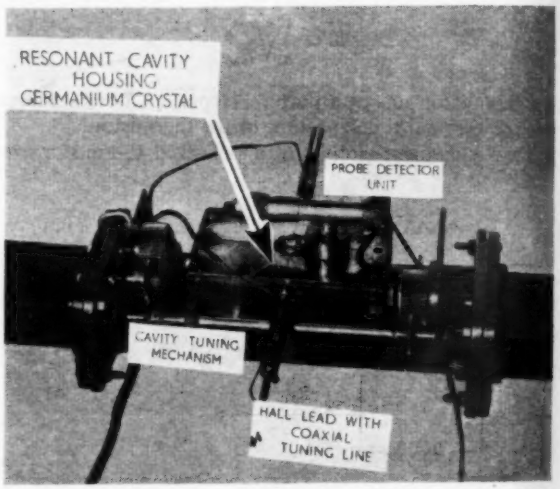
Hall Effect at Microwave Frequencies

A short review of a Radio and Telecommunication Section Paper (No. 1913) entitled "The Hall Effect and its Application to Power Measurement at Microwave Frequencies," by Professor H. E. M. Barlow, Ph.D., B.Sc.(Eng.), Member, and L. M. Stephenson, B.Sc.(Eng.), Associate Member. The paper was published in January, 1956, in Part B of the Proceedings.

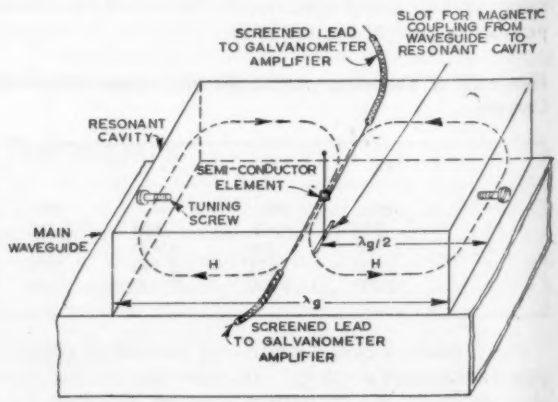
WHEN A PIECE OF A SEMI-CONDUCTOR, SUCH AS GERmanium, is placed in an electromagnetic field, the mobile carriers responsible for the current through the material are subjected to a pressure perpendicular to the electric and magnetic components of the field. This is the Hall effect well known under d.c. and low-frequency a.c. conditions but now shown to exist in much the same way at 4 000 Mc/s.

Since the Hall effect is proportional at any instant to the product of the applied electric and magnetic field strengths, the e.m.f. arising from it gives a measure of the power passing through the semi-conductor. Preliminary work has been done to develop an instrument based on this principle. The semi-conductor element is mounted in a resonant cavity coupled to the waveguide carrying the microwave power. The apparatus is shown in Fig. 1 and diagrammatically in Fig. 2. This arrangement enables the semi-conductor element to be immersed in a comparatively strong magnetic field and allows the electric field to be so controlled that any residual rectifier action is substantially eliminated.

The mean value in time of the Hall e.m.f. is measured


RESONANT CAVITY HOUSING GERMANIUM CRYSTAL
PROBE DETECTOR UNIT
CAVITY TUNING MECHANISM
HALL LEAD WITH COAXIAL TUNING LINE

1 *Apparatus for measuring microwave power*



2 *Semi-conductor element mounted in resonant cavity*

by means of a galvanometer associated with a photocell amplifier, and an output of 5μV is obtained for about 1 watt in the main guide, 12–15% of this power being absorbed by the instrument. Further work is required to elucidate some of the conditions of operation and to develop the measuring technique. There can be no doubt, however, that a new method of microwave power-measurement has been established, yielding an instrument capable of use under any conditions of load, matched or otherwise, without absorbing more than a fraction of the power being transmitted.

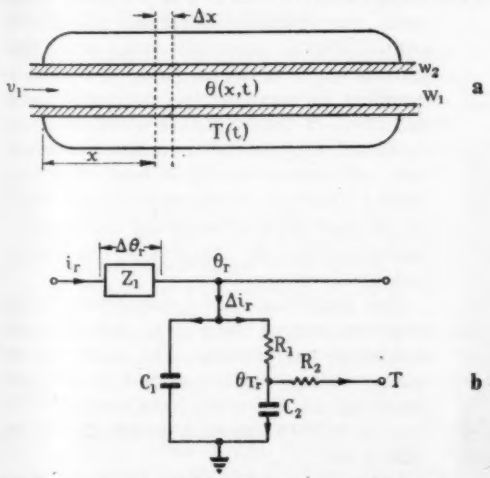
621.317.382.029.6 : 538.632

Heat-Exchanger Analogues

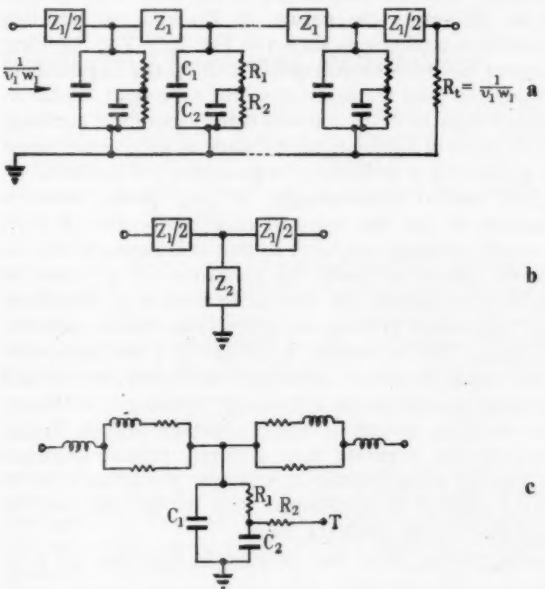
A short review of a Measurement and Control Section paper (No. 1934) entitled "Electrical Analogues for Heat Exchangers," by R. L. Ford, B.Sc., Ph.D., Graduate. The paper was published in January, 1956, in Part B of the Proceedings.

AT THE PRESENT TIME THE OUTSTANDING PROBLEM IN THE field of automatic process control is the lack of information on plant characteristics. One of the reasons for this is the complexity of modern processes, which has the further result that, even where the required data are available, the plant transfer function is often so formidable that a purely mathematical approach to the control problem is extremely laborious. Certain distributed-parameter heat exchangers fall into this category but a solution is possible by means of electrical analogues if these can be made sufficiently accurate without undue complication. The associated requirement for an electrical analogue of the usual three-term process controller can easily be satisfied. A three-term controller produces an output proportional to the deviation of the controlled quantity from the control point plus the integral and the first derivative of the deviation with respect to time.

In an initial approach to the problem of deriving an analogue for a distributed-parameter thermal system it is desirable to consider first of all the simplest possible arrangement. This is illustrated by Fig. 1(*a*) and consists of a tube, which carries a fluid flowing with velocity v_1, immersed in a jacket of infinite thermal capacity. If we divide the tube into a number of elements of length Δx, a lumped-constant electrical analogue can be derived for each section. These may then be connected together in a suitable manner to form an analogue for the complete system. Fig. 1(*b*) shows the analogue of the rth element of length Δx of the heat exchanger, certain simplifying



1 *The constant-jacket-temperature heat exchanger*
(*a*) Schematic.
(*b*) Analogue of an element of length Δx.



2 *The analogue as a four-terminal ladder network*
(*a*) Complete analogue with $T = 0$.
(*b*) A T-section of the network with $T = 0$.
(*c*) Components of the T-section, $T \neq 0$.

assumptions being made. For the present purpose the most important of these is that the tube is assumed to have infinite and zero thermal conductivity in the radial and axial directions respectively. The circuit is based on the analogy between voltage and temperature and between current and heat flow, so that C_1 and C_2 represent the thermal capacitances of the inner fluid and the tube, respectively, while R_1 and R_2 represent the resistances to heat flow at the inner and outer surfaces of the tube. The voltages θ_r and θ_{Tr} are measures of the temperatures of the inner fluid and the tube, respectively, at a point distant $r\Delta x$ from the inlet. The voltage T, representing the temperature of the outer fluid, is the same for all sections. The series impedance Z_1 has no physical

equivalent in the heat exchanger but its presence is justified by the need for a voltage gradient along the analogue similar to the temperature gradient along the heat exchanger.

Further consideration leads to a complete analogue of the form shown in Fig. 2. In Fig. 2(*a*) the resistors R_2 have been returned to earth instead of to a common, low-impedance source of potential T as would normally be the case. Thus, for $T = 0$, the analogue reduces to a four-terminal ladder network and it is convenient to represent each elementary analogue as a T-section of the form shown in Fig. 2(*b*), where Z_2 is the impedance of a shunt arm of the circuit of Fig. 2(*a*). It can be shown that the characteristic impedance of the network is required to be $1/v_1w_1$, where w_1 is the thermal capacity of the inner fluid per unit length of the tube. This enables us to determine the nature of Z_1, and the resulting elementary analogue is shown in Fig. 2(*c*). The complete network is fed with voltages T and θ_i, the latter representing the inlet temperature of the tube fluid. So far as disturbances in θ_i are concerned the theoretical accuracy of this form of analogue can be made as good as we please by employing a sufficiently large number of sections.

The major disadvantage of the passive-network analogue is that the value of each component of Z_1 is inversely proportional to v_1^2 so that it is impracticable to use the circuit to study the behaviour of a system in which v_1 is variable. An alternative method of simulating the temperature gradient along the inner fluid is therefore desirable. This is possible by means of a feedback technique using electronic amplifiers; the shunt arm of each elementary analogue being basically unchanged. Although the resulting system is more complex and is fundamentally less accurate than a purely passive analogue having the same number of sections, it enables v_1 to be varied since it is represented only by the gains of the amplifiers in the feedback loops.

The steady state and frequency responses of both types of analogue are derived in the paper and compared with those for the heat exchanger. Consideration is also given to a more practical type of heat exchanger in which the thermal capacity of the outer fluid is finite and the flow through the outer vessel continuous. Some experimental results for a passive-network type of analogue for this heat exchanger were obtained and they show that a satisfactory performance is possible with a reasonable number of sections.

621.3.012.8 : 621–52 : 628.8

A.C. Supply for Calibration

A short review of a Measurement and Control Section paper (No. 1937) entitled "An Electronic Supply for Use in the Calibration of Instruments," by F. J. Wilkins, B.A., B.Sc., and S. Harkness, Graduate. The paper was published in January, 1956, in Part B of the Proceedings.

UNTIL RECENT YEARS THE DEMAND FOR THE ACCURATE calibration of a.c. instruments was confined to frequencies below 500 c/s, and in order to provide supplies for this work the Electrotechnics Section of the National Physical Laboratory was equipped with a number of alternators which were suitably designed to produce a good waveform and driven by d.c. motors supplied by lead-acid storage batteries to give the required output-voltage constancy. When the supply facilities were extended to enable instruments to be tested at higher frequencies the alternator system was no longer satisfactory and an electronic supply was installed.

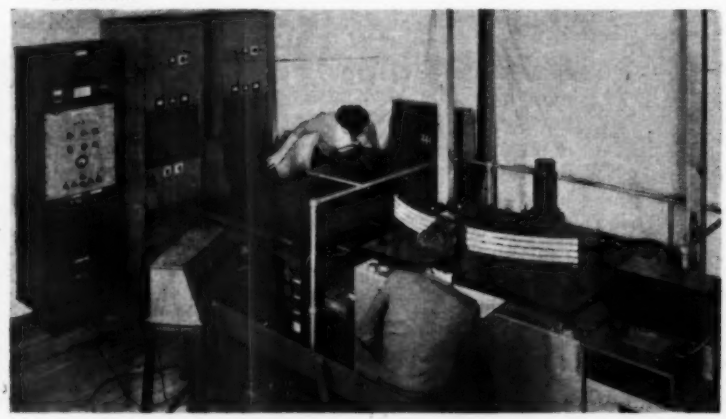
Experience with this supply, which enabled a total output of between 160 VA and 320 VA to be developed from four amplifiers in the frequency range 300 c/s — 100 kc/s, showed that it had many attractive features: the output voltage was more constant than that of the alternators, the distortion was low, the frequency was constant and independent of load and yet could be varied easily, the system was compact and easy to control and the equipment could be supplied directly from the mains. Another oscillator-amplifier set was therefore developed and is described in the paper. It consists of an oscillator, a phase-shift unit and two amplifiers and gives a double output of at least 700 VA in the frequency range 30 c/s–5 kc/s, thus greatly increasing the range of electronic supplies available in the Electrotechnics Section.

The oscillator is of conventional design and great care is taken to eliminate supply-frequency components. The drift in the output voltage seldom exceeds 0·02% per hour, the distortion does not exceed 0·15% and the supply-frequency component is less than 0·002%.

In the phase-shift unit the change of phase is made by varying the values of resistors in *CR* networks which are connected across

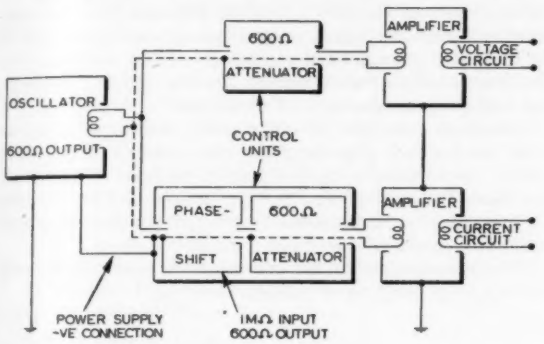
1 *Calibration of a wattmeter*

The oscillator, amplifiers, phase shift and attenuator unit for the current supply, the attenuator for the voltage supply, the instrument under test and the standard instrument are shown.



voltages of $+v$ and $-v$ developed in two phase-splitting circuits. The system does not introduce any appreciable distortion and the voltage constancy is at least equal to that of the remainder of the equipment.

Each amplifier consists of five push-pull stages across



2 *Connections for a double supply*

which 34–36 dB of harmonic feedback is developed. The amplifiers may be driven directly from the oscillator to give two outputs of the same phase, which may be connected in series, or one may receive its signal through the phase-shift unit so that the phase of this output may be varied with respect to the other. This second method of connection is commonly used for testing wattmeters and Fig. 1 shows a typical arrangement. The schematic system of connections for the supply is shown in Fig. 2. Each amplifier will develop 700 VA in the range 30 c/s–5 kc/s, and 900 VA in the range 50 c/s–3 kc/s. As the output stage is operated in Class AB_2 the available output is dependent on the power factor of the load, and at 50 c/s falls to 250 VA at zero power factor. This decrease in the available output seldom restricts the use of the amplifiers in the calibration of instruments as resistive loads are nearly always used. Power-factor compensation could be applied if necessary.

The supply-frequency component in each oscillator-amplifier output does not exceed 0·01%; the maximum drift, which occurs when an amplifier is developing an output of 900 VA, is 0·01% in three minutes; and the distortion is seldom greater than 0·35%.

621.373.42 : 621.311.6 : 621.317.7.089.6

Oscillating-Electrode Voltmeters

A synopsis of a Measurement and Control Section paper (No. 1966) entitled "A Note on the Theory of Oscillating-Electrode Voltmeters," by J. Rawcliffe, M.Sc.(Tech.), Associate Member. The paper is published this month in Part A of the Proceedings.

IT HAS BEEN TACITLY ASSUMED HITHERTO THAT THE THEORY of the oscillating-electrode voltmeter derived for direct voltages applies equally well for alternating voltages if r.m.s. values are substituted for direct values. A rigorous treatment shows that this is not so. 621.317.72.082.72

OBITUARY

HENRY ROTTENBURG

Henry Rottenburg, who died on the 25th March, 1955, was born on the 6th October, 1875. He was the son of Paul Rottenburg, chemical merchant of Holmhurst, Downside, Glasgow. He attended school both at Loretto and at Kelvinside Academy, and was admitted to King's College, Cambridge, in 1895. He read Part II of the Mathematical Tripos and took a first class honours in the Mechanical Sciences Tripos in 1894, as did Miles Walker in the same year. He was awarded his blue for Rugby football and was a Scottish International player from 1899 to 1900. In the latter year he joined the Westinghouse Co. at Pittsburg, U.S.A., becoming a member of the famous "Holy Forty," and remained with them until 1902, when he joined the new British Westinghouse Co. at Trafford Park. In 1904 he left them to return to Cambridge as a lecturer in engineering, but left there in 1908 to join the J.L. Submersible Motor Co. In 1910 he returned to his lectureship at Cambridge and remained in residence until his death in his 80th year.

He was a man of superb knowledge of all technical matters and of an inventiveness which is seldom matched. For some 30 years he ran the London Instrument Co. in Cambridge, which he started mainly to develop his own ingenious and very varied inventions. For the last twenty years he specialized in equipment for assisting in various athletic contests; some of them were used in the Olympic Games at Helsinki. This widely gifted man had a deep interest in dramatic art, was a playwright and producer, and a writer and singer of witty comic songs. Perhaps a founder member of the Footlights Club, he wrote and produced several of their May-week plays, from his undergraduate days onwards. The great work of his long and active life was devoted to helping the undergraduate, in the lecture room and laboratory, on the stage and on the Rugby football field. Some pupils, especially those with conventional minds, were apt to find him unsatisfactory as a teacher, while many others found him quite the reverse; the patient listener knew that Harry would periodically drop priceless gems of knowledge or ideas, which could be gathered eagerly from among a welter of rather random talk. He who writes this note owes a very great debt to Harry for much quite remarkable teaching, and for a lifetime of warm friendship and kindness. Harry was never out of temper, never dull, always kind and generous, while at the same time often exuberant beyond the point of comfort, and over loquacious. His enthusiasm never flagged nor did a rather lonely later life ever sadden him. A short illness and he was gone, much the same man throughout the last forty years. Most who knew him will miss him to the end.

About 1911 he married a daughter of Sir Trevor Laurence of the Thames Iron Works; she died about 1933. He is survived by a son and a daughter.

He joined The Institution as a Member in 1912. E. B. M.

MONOGRAPHS AND PAPERS
published separately this month

Details of the cost and availability of separately published monographs and papers may be found on page 50 of the January issue of the *Journal*. Synopses of monographs and papers which will be published separately before the next issue of the *Journal* appear below, and unless otherwise stated, their date of publication is the same as this issue of the *Journal*. The monographs will be republished in Part C of the *Proceedings*, and the relevant Part for the republication of a paper is given after the serial number of the paper.

The papers whose titles are marked with an asterisk are ones to be presented at the Conventions on Digital Computer Techniques (9th–14th April, 1956) and on Electrical Equipment of Aircraft (2nd–4th May, 1956). During the period of ten days before the relevant Convention (and at the Convention itself) such papers will not be available free, as is customary for most papers, but those who have registered for the Convention will be able to obtain them on payment of a nominal sum. See January *Journal*, page 22, and this issue, page 124.

MONOGRAPHS

Note on the Fourier Coefficients for Chebȳshev Patterns

MONOGRAPH No. 166 R

H. E. SALZER

The main purpose of the monograph is to obtain a single formula for calculating feeding coefficients for optimum beam patterns. The new formula derived is equivalent to a set of formulae given by DuHamel, but is much simpler in form and more convenient for computation. It is applicable to Riblet's generalization of Dolph's procedure for finding optimum beam patterns in the design of linear arrays, for an odd number of elements when the distance between sources is less than half the wavelength. Whereas DuHamel's formulae involve a number of separate summation expressions, each of which has terms involving considerable multiplication and division, the corresponding terms in the present, more concise, expression have simpler integral coefficients.

Radiation Patterns of Circumferential Slots on Moderately Large Conducting Cylinders

MONOGRAPH No. 167 R

J. R. WAIT, M.Sc., Ph.D., and J. KATES

The monograph presents computed patterns for thin half-wave circumferential slots on circular conducting cylinders of infinite length. Single and diametrically opposed slots on cylinders whose circumferences vary from 3 to 21 wavelengths are considered.

Some Properties of Magnetrons using Spatial Harmonic Operation

MONOGRAPH No. 168 R

R. G. ROBERTSHAW and W. E. WILLSHAW, M.B.E., M.Sc.(Tech.)

To reduce the problems involved in the design of magnetrons of low voltage and power for operation at frequencies of the order of 10 000 Mc/s and higher, a system is proposed in which the anode has only a few gaps, e.g. two or four. Operation at low anode voltage and magnetic field is achieved by electron interaction with the Fourier space components of the field.

A convenient and simple embodiment is described, and factors likely to result in operation different from the conventional multiple-circuit magnetrons are analysed briefly. In particular, the modes of oscillation and the magnitudes of the components of the different possible spatial harmonics are discussed for two types of anode circuit.

Details of operation of valves using both types of anode with two and four gaps are given, and comparisons are made where appropriate with the earlier analysis. The simple electrical structure of the two-gap anode enables a useful tuning range to be obtained by external-circuit adjustment, and some details of tuning performance are given.

The paper concludes with comments on noise performance and speed of build-up of oscillations.

PAPERS

A Self-Oscillatory Induction Motor for Shuttle Propulsion

PAPER No. 1988 U; PART A

E. R. LAITHWAITE, M.Sc., and P. J. LAWRENSON, B.Sc.

An induction motor can be constructed so as to produce a magnetic field travelling in a straight line. Such a device can be used to propel a shuttle across a loom. The paper describes a stator arrangement by which the shuttle can be caused to oscillate without the use of switches. With suitable design there is an inherently stable condition. Expressions are derived for the amplitude and period of this oscillation, for an unloaded motor, and for a motor operating against a constant load force. These are used to derive theoretical curves and phase-plane diagrams which are compared with those obtained in practice.

The Indirectly Heated Thermistor as a Precise A.C.-D.C. Transfer Device

PAPER No. 1989 M; PART A

F. C. WIDDIS, B.Sc.(Eng.)

The paper is an investigation into the possibilities of using an indirectly heated thermistor as a precise a.c./d.c. transfer device over a wide range of frequencies. The thermal drift inevitable with such a device has been examined and a procedure for its elimination developed, resulting in very high thermal stability. Experiments made on the reproducibility of the thermistor seem to indicate a complete absence of hysteresis over the working range.

It is shown that the device is extremely sensitive and is therefore useful for general laboratory work with simple equipment, although this advantage is somewhat outweighed by the slow response.

Experimental results are given for the d.c. reversal errors due to Peltier and Thompson effects; these are found to be quite small.

An analysis of the effects of frequency shows that, owing to the large thermal time-constant, the indirectly heated thermistor in its present form, can be used at frequencies as low as 0·2 c/s, thus well below the working range of normal measuring devices.

Transistor Arithmetic Circuits for an Interleaved-Digit Computer*

PAPER No. 1992 M; PART B

R. C. M. BARNES, B.Sc.(Eng.), G. A. HOWELLS, and E. H. COOKE-YARBOROUGH, M.A.

Earlier papers have described transistor circuits for use as computer elements. This paper describes the development of these, and various gating circuits, as the standard elements from which a digital computer has been constructed. The application of the standard circuits to the arithmetic unit of the computer is illustrated by two examples: an adder of unusual, yet logical, design to suit the interleaved-word storage system, and a multiplier system which forms the signed product of two 31-digit binary words in six word-times. A general description of the computer, and details of the magnetic-drum store, are given in accompanying papers.

Time Sharing as a Basis for Electronic Telephone Switching: A Switched-Highways System

PAPER No. 1993 R; PART B

L. R. F. HARRIS, M.A.

The paper will be published in March

All telephone systems incorporate time-sharing techniques in order to economize in apparatus, but the extent of their application depends upon the operating speeds and adaptability of the components used. The introduction of electronic techniques enables various switching, coding and sampling techniques to be used to achieve increased time sharing.

In a system now under development these principles are the main basis of design. Connections are made over common leads using pulse channels each of which may be used for connections to any line. The connections are controlled by register and supervisory apparatus in which information is received, stored, manipulated and transmitted by common apparatus that operates on the connection pulse channels. Common selecting, translating and marking apparatus is used to set up all connections on a one-at-a-time basis, and all apparatus apart from the line-terminal equipment is time-shared by the connections, by using either sampling or switching techniques.

The capital and maintenance costs of such a system are as yet indeterminate, but it is expected that they will be competitive.

Aircraft Electrical Cables*

PAPER No. 1994 U; PART A

D. W. BIRD, B.Sc., D. C. HANCOCK, B.Sc., Ph.D., and D. B. McKENZIE, B.Sc.

An account of early cables is followed by a statement of present-day requirements.

Descriptions of the standard cables are given together with data on current rating. Further needs and possible designs are indicated.

An Interleaved-Digit Magnetic-Drum Store for a Transistor Digital Computer*

PAPER No. 1999 M; PART B

J. H. STEPHEN, Ph.D., and E. H. COOKE-YARBOROUGH, M.A.

The magnetic-drum store for a small transistor digital computer operating at 58 kc/s is described. The logical design of the computer requires the interleaving of the digits of the words—an arrangement which makes many words on the drum available concurrently and therefore permits economical 3-address operation. The working store has a capacity of 426 words, including a regenerative loop which is necessary for temporary storage, since not all the words are available concurrently. The proposed main store, which will be relay selected, has a capacity of 16 384 words. Circuits are described for writing and reading the interleaved words on to and from the drum and for producing the timing pulses for the whole computer. A general description of the computer, and details of the arithmetic circuits, are given in accompanying papers.

The Method of Lanczos for Calculating the Characteristic Roots and Vectors of a Real Symmetric Matrix*

PAPER No. 2017 M; PART B

R. A. BROOKER, M.A., and F. H. SUMNER, Ph.D.

The paper draws attention to a method suggested by Lanczos for arriving at the reduced characteristic function of a matrix, and shows how it may be used with an electronic computer to evaluate automatically the characteristic roots and vectors of a real symmetric matrix, no matter how degenerate.

Underground Lighting in Coal-Mines

PAPER No. 2034 U; PART A

C. D. J. STATHAM, Ph.D., B.Eng.

The paper will be published on March 5th.

The importance of lighting below ground is emphasized and the difficulties associated therewith are outlined. Inadequate or inferior lighting produces nystagmus and mention is made of the decline in the incidence of new cases where better lighting has been introduced.

Changes in portable lamps, embodying improvements in technique and alterations to suit mining methods, are reviewed and descriptions of typical modern equipment and methods of application included. The importance of photometry in lamp-room practice is discussed and a description is given of the test procedure employed.

The desirability of extending the use of mains lighting below ground both for the roadways and the coal-faces is indicated. Progress in this field is reviewed together with descriptions of equipment and results obtained. It is pointed out that the economic aspect of the general introduction of mains lighting to coal-faces will be an important factor. Developments are hindered by restrictions in the use of aluminium alloys in coal-mines.

The Application of Transistors to the Trigger Ratemeter and Power Supply Circuits of Radiation Monitors

PAPER No. 2049 M; PART B

E. FRANKLIN, M.Sc.(Eng.), Ph.D., and J. B. JAMES

The paper will be published on March 17th.

The paper outlines the general requirements and the conditions of use of radiation monitors employed in gamma- and beta-ray survey in connection with geological prospecting. In such instruments, it has been usual to employ either filament valves or cold-cathode valves in amplifier and trigger circuits, and vibrators, filament-valve oscillators or high-voltage battery stacks in the power supplies. Arguments leading to the transistor as the preferable component for all such instruments are given and typical transistor circuits are discussed in some detail. The paper considers both point-contact and junction transistors, and demonstrates the superiority of the junction-transistor circuits for this type of application.

BRITISH NUCLEAR ENERGY CONFERENCE

The following paper will be read at a meeting of the Conference on the 20th March, 1956 (see page 126). Advance copies of it will be available from the General Secretary, The Institution of Chemical Engineers, 56 Victoria Street, London, S.W.1; applications for these should include a stamped addressed label or envelope (preferably 9 in. × 6 in.).

The Application of Fluidization Techniques to Nuclear Reactors

C. M. NICHOLLS, B.Sc.(Eng.), J. B. MORRIS, Ph.D., and F. W. FENNING, B.A.

Fluidization techniques are used in industry where temperature control and heat removal are important, and they should therefore be applicable to nuclear reactors. Fuel investment considerations lead the authors to favour a reactor working with "thermal" rather than with "fast" neutrons. On considerations of nuclear physics alone a number of systems can be postulated.

Simple gas cooling may be used if the size of particles to be cooled is larger than is normal in industrial practice and if the gas is under a pressure of about 100 atmospheres. There is little difference of efficiency between different gases.

If liquid fluidization is considered it is found that pressurized water has the best heat transport capacity. In non-pressurized systems the liquid metals sodium and lithium give the best heat removal. Since the temperature rise that can be tolerated for pressurized water is much lower than for liquid metals, the latter give the more favourable overall heat removal (transfer plus transport).

A mixed phase system would give favourable heat removal. In this type of system a gas is used for fluidization and a liquid is injected into the bed, the temperature of which is above the boiling point of the liquid, which flash evaporates, causing a large proportion of the heat to be removed as latent heat. A mixed phase system would in practice probably utilize water and steam.

Whatever system was selected a very large effort would have to be expended on research before it could be decided that the system was really feasible. Research would have to cover the fluidization characteristics of the selected system, flow velocities of fluidizing media, transient density behaviour, heat transfer, erosion, corrosion and attrition. Owing to the intense toxicity of the materials methods would have to be devised to ensure that no dusts or liquid sprays could escape into the atmosphere. Fluidization techniques would indeed have to be engineered to an unprecedented standard.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH JANUARY, 1956

£1 000 and over	6	6000	0	0
£100 to <£1 000	29	6386	3	0
£5 to <£100	778	8490	18	11
£2 to <£5	1868	5156	3	2
Under £2	18506	9793	5	3
		£35826	10	4

HONOURS AND DISTINCTIONS CONFERRED ON MEMBERS

NEW YEAR HONOURS LIST

The names of the following members of The Institution were included in the New Year Honours and Distinctions conferred by Her Majesty:

C.B.
Couch, W. C. M., C.B.E. (*Member*).
Mann, Air Comm. W. E. G., C.B.E., D.F.C. (*Member*).

C.M.G.
Wilkinson, E. R. (*Member*).

C.B.E.
Booth, Capt. C. F., O.B.E. (*Member*).
Lithgow, J. C. (*Member*).

O.B.E.
Huggett, W. J. (*Associate Member*).
Oatley, C. W., M.A., M.SC. (*Member*).
Rawlinson, J. D. S., B.SC.(ENG.) (*Member*).
Sims, A. E. (*Associate Member*).
Weston, H. (*Member*).

M.B.E.
Essex, G. W. (*Associate Member*).
Gunn, G. (*Associate Member*).
Harral, R. H. (*Member*).
Rogers, D. C. (*Associate Member*).

HONORARY MEMBER

At an Ordinary Meeting of The Institution on the 2nd February, 1956, the President announced that the Council had elected to Honorary Membership of The Institution, **Colonel Sir Arthur Stanley Angwin, K.B.E., D.S.O., M.C., T.D., D.Sc.(Eng.) (President 1943–44),** in recognition of his outstanding life's work in the field of telecommunication, both national and international, and of his distinguished services to The Institution.

FARADAY MEDAL

At the Ordinary Meeting of The Institution on the 2nd February, 1956, the President announced that the Council had made the Thirty-Fourth Award of the Faraday Medal to **Emeritus Professor George William O. Howe, D.Sc., LL.D., Member,** in recognition of his pioneering work in the study and analysis of high-frequency oscillations and on the theory of radio propagation; and for his outstanding contributions to engineering education.

EARLY RELEASE OF INFORMATION TO THE TECHNICAL PRESS

To enable the technical Press to publish as soon as possible new material of topical technical interest dealt with in papers accepted for reading before The Institution, an author of such a paper is at liberty to offer a more popular, less tech-

nical and shorter article for publication in the technical Press prior to the reading of his formal Institution paper on the same subject, provided that the article does not appear before the paper has been published separately (see page 120) and that the article makes reference to the paper.

Similarly, the author of a paper which has been accepted for publication only may proceed forthwith to prepare a more popular, less technical and shorter article for the technical Press, but it must not appear before the paper has been published in the *Proceedings* or as a *Monograph*, and it must be accompanied by a suitable acknowledgment.

SUPPLY SECTION

The Supply Section have arranged two visits during this Session.

The first will be held on Saturday, 5th May, 1956, when in the morning, a visit will be made to the Houses of Parliament. After lunch in the Members' Dining Room the party will leave by steamer for Greenwich, where the National Maritime Museum, and the Painted Hall and Chapel of the Royal Naval College, will be seen. Tea will be taken at Greenwich before the party returns by steamer to Westminster Pier. A circular giving further information to members of the Supply Section will be sent out with this issue of the *Journal*.

The main Visit of the Section will be to Northern Ireland from the 6th to 9th September, 1956. The programme will include a number of visits of technical and general interest in addition to the usual evening social functions. Preliminary details of the Visit have already been notified to members of the Section with the application form for the Dinner-Dance on the 6th March, 1956.

PROGRESS REVIEW OF FERROMAGNETISM

In this month's issue of Part A of the *Proceedings* there appears a progress review (Paper No. 1947) by Professor F. Brailsford, PH.D., B.SC.(ENG.), MEMBER, entitled "Ferromagnetism in relation to Engineering Magnetic Materials." This review is concerned mainly with theoretical and experimental work on ferromagnetism carried out during the last ten years, and it brings up to date part of a previous review of magnetic materials by Professor Brailsford and other authors that was published in the *Journal* in 1948.

The review begins as follows:

> The theory of ferromagnetism, in its finer detail, continues to offer many hard problems to the physicist and mathematician. A discussion of the outstanding difficulties would take the engineer into deep water. But in spite of some obscurities there exists a satisfying general picture of the subject, which has, in fact, been illuminated in the past ten years by notable theoretical and experimental work. Some of this work clearly discloses the underlying macroscopic structure of ferromagnetic materials.
>
> During this period also new magnetic phenomena occurring at high frequencies have been observed in the ferromagnetic metals and in that increasingly important class of engineering magnetic materials known as the ferrites.

There follows a brief introductory account of the earlier development of ferromagnetism, which leads on to a more detailed survey of recent work including an account of ferromagnetic domains and the small-particle theory of high coercivity. Next comes a section on ferrites, of special interest to members at the present time in view of the Convention on the subject to be held by The Institution later this year. In this section the author considers particularly crystal structure and "ferrimagnetism," and he gives a table showing the ion site, magnetic moment and direction of magnetic axis of various ferrite substances.

The fourth part of the review is concerned with magnetic phenomena at high frequencies. It includes a discussion of gyromagnetic resonance. Professor Brailsford ends on a note of anticipation of new materials and new applications, and by appending a comprehensive bibliography.

SPECIAL COURSES IN HIGHER TECHNOLOGY

The second part of the programme of specialized courses to be held at technical colleges in London and the Home Counties during the Spring and Summer Terms, 1956, has been issued by the Regional Advisory Council for Higher Technological Education. The courses, most of which are part-time, cover a wide range of subjects including electrical and mechanical engineering, mathematics, physics, chemistry, metallurgy, management, accountancy, industrial law, engineering economics, organization and statistics. The fees are usually 10s. for six lectures up to a maximum of £2, although prospective students should consult the college concerned for the correct details of a particular course.

Further information may be found in the "Bulletin of Special Courses in Higher Technology," obtainable from the Secretary, Regional Advisory Council, Tavistock House South, Tavistock Square, London, W.C.1, price 1s. 6d., post free.

MEMBERS TRAVELLING TO AND FROM THE UNITED KINGDOM

Members visiting or taking up residence in the areas of any of the Oversea Branches, Oversea Committees or Joint Oversea Groups, which were listed on pages 68 and 69 of the January issue, are invited to apply to the Secretary of The Institution for a letter of introduction to the appropriate Honorary Secretary.

The Secretary will be obliged if members coming home from oversea will inform him of their addresses in this country, even if they do not desire a change of address to be recorded in the Institution register. This will enable him to advise such members of the various meetings, etc., of The Institution and its Local Centres, and, when occasion arises, to put them in touch with other members.

The Secretary will be pleased if those members from oversea who are able to visit the Institution premises will call upon him.

SUBSCRIPTIONS AND NATIONAL SERVICE

It has already been announced that the subscription of a Student Member is payable at the rate of 10s. per annum while he is carrying out his National Service. The Council have now decided that this concession shall be extended to Graduates.

The special rate will apply to Graduates from the 1st January, 1956, and those called up during the year 1955 may claim the reduction of their subscriptions in respect of the year 1956. The new ruling will not operate retrospectively.

DISCUSSIONS AT MEETINGS

The Council desire it to be understood that contributions to the discussions at meetings should not be read from manuscript, since they consider that this form of presentation is contrary to the true spirit of a discussion.

THE INSTITUTION STAFF: EDITORIAL VACANCY

There is a vacancy for an editorial assistant for work on the *Proceedings* of The Institution. The qualifications required are an engineering or a science degree, some engineering experience, and the ability to sub-edit high-class technical copy. A knowledge of foreign languages would be advantageous. Applicants should be between the ages of 25 and 30 (approximately). The salary will depend on age, qualifications and experience. Entry to a superannuation scheme would follow a short period of service.

Those who are interested should write to the Secretary, The Institution of Electrical Engineers, Savoy Place, London, W.C.2, giving full particulars of their education, training and experience.

FIFTY YEARS OF MEMBERSHIP

The Council take much pleasure in placing on record the completion of fifty years of membership of The Institution by the members whose names appear below; they first became associated with The Institution in the year 1906.

Ainsworth, J. S.
Aitken, S.
Bamford, H.
Barnes, J. A. T.
Broughton, H. H.
Castello-Sosa, A.
Claret, W. E.
Clark, A. B.
Coulthard, R. D.
Cox, G.
Craske, H.
Dannatt, F. C., O.B.E.
Denham, H. Y.
Douglas, A.
Edridge, W. H.
Edstrom, J. S.
Edwards, W. V.
Ellis, H. S.
Evans, W. T.
Falkenbach, A.
Fraser, A. R.
Golding, R. A.
Good, C. N.
Groom, H. R. L., D.S.O., M.C.
Hamilton, A.
Harris, P.
Heaton, W. H.
Heynssens, J.
Higgs, W. F.
Jackson, W. A.
Jakeman, R. G., D.SC.
Kelso, J. C.
Kinghorn, D. M.
Kinnes, A., B.SC.
Lamb, H. C.
Latif, H. C. A. A.
Le Feuvre, C. G.
Leonard, L. D.
Leys, G. D.
Lunn, E.
MacGregor, W. D., C.I.E.
McKinnon, E. C.
Mears, A.
Morton, E. R.
Midgley, A. R.
Parkinson, F. W.
Penning, S. H.
Prangnell, Lt.-Cmdr. N. W.
Ritter, E. S.
Roberts, G. A.
Sadd, Major J. A., O.B.E.
St. John, E. C.
Scott, H. S.
Sheldon, R. A.
Skinner, H. J.
Smith, G. E. J.
Smith, J. R.
Spark, J. W.
Stevens, E. J.
Stewart, W. C.
Taylor, J. A.
Turle, E. H.
Warren, A. G.
Watson, E. A., O.B.E., D.SC.(ENG.).
West, T. H.
Wrigley, C. R.

ILLUMINATING ENGINEERING SOCIETY

SUMMER MEETING AT HARROGATE

The I.E.S. Summer Meeting will take place at Harrogate from the 8th–11th May, 1956. The meeting (which is a biennial event) will include the reading of technical papers by lighting engineers from many countries, a display of new lighting equipment, and visits to factories and actual lighting installations in the surrounding area. A special programme is being prepared for ladies and there is a sprinkling of social events. Visitors from oversea may be interested in a pre-meeting coach tour arranged for them, which will enable them to see some of England's beauty spots and places of historical interest.

Members of the Utilization Section are reminded that their Summer Visit to Harrogate is from the 11th–13th May. The two functions will not overlap and members interested in illumination engineering could attend both of them consecutively.

The registration fee for the I.E.S. meeting is £2 for non-members of the Society. Further details may be obtained from the Secretary, The Illuminating Engineering Society, 32 Victoria Street, London, S.W.1.

Application forms for the Utilization Section visit will be sent to all members of the Section with the March issue of the *Journal*.

THE EFFICIENT USE OF TECHNICAL PERSONNEL

Owing to illness the President, Sir George Nelson, was unable to be present at the Informal Meeting on the 9th January, 1956, to open a discussion on the subject "The Efficient Use of Technical Personnel," previously arranged for this meeting, and at short notice Mr. J. Eccles opened a discussion on "Do Engineers make Good Managers?"

An additional Informal Meeting has now been arranged for the 30th April, 1956, when the President will open the discussion on "The Efficient Use of Technical Personnel."

ELECTRICAL EQUIPMENT OF AIRCRAFT

2ND–4TH MAY, 1956

As previously announced, the Committee of the Utilization Section are arranging a Convention on 'Electrical Equipment of Aircraft' to be held at the Institution building from the 2nd to 4th May, 1956. The provisional plan for the Convention is as follows:

Wednesday, 2nd May

Evening	Opening Session—The proceedings will be opened by the Rt. Hon. Reginald Maudling, M.P., Minister of Supply.

Thursday, 3rd May

Morning	Session 2—Electricity in Aircraft
Afternoon	Session 3—Aircraft Electrical Systems
Evening	Session 4—Machine Equipment

Friday, 4th May

Morning	Session 5—System Equipment
Afternoon	Session 6—Installation and Maintenance

As many as possible of the papers to be presented will be available in advance on payment of a nominal fee, and the complete proceedings of the Convention will be published subsequently in a supplement to Part A of the *Proceedings*.

The Convention is open to members and non-members of The Institution, the latter being required to pay a registration fee of £1. Those who wish to attend, whether members of The Institution or not, should apply to the Secretary of The Institution (subscribers to Part A of the *Proceedings* and members of the Utilization Section will find a reply form for this purpose enclosed with this issue of the *Journal*) for a registration form which will be sent to them later, together with further details of the Convention. Application for copies of the papers and for the supplement to Part A of the *Proceedings* should be made on the registration form.

OVERSEA ATTENDANCE REGISTER

During the period 1st December to 31st December, 1955, the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

BOSE, S. (Simla, India).
DE BEER, C. L. (Johannesburg).
FOLLETT, J. S. (Rio Grande, Brazil).
HOY, H. L. (Lower Hutt, New Zealand).
KELKAR, P. K., PH.D., B.SC. (Bombay).
ROY, R. N. (Calcutta).
WHYTE, W. L. (Kuching, Sarawak).

Forthcoming Events at Savoy Place

All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E	EDUCATION DISCUSSION CIRCLE	**R**	RADIO AND TELECOMMUNICATION SECTION
I	INFORMAL	**S**	SUPPLY SECTION
M	MEASUREMENT AND CONTROL SECTION	**U**	UTILIZATION SECTION
O	ORDINARY		

After each paper that has now been published is added the month that its synopsis appeared in the *Journal*.

1956

FEBRUARY

22 *Wednesday*

B. C. ROBINSON, PH.D., M.SC. **S**
"The Penetration of Surge Voltages through a Transformer coupled to an Alternator" (Paper No. 1997 S)‖
"The Propagation of Surge Voltages through Turbo-Alternators with Concentric-Conductor-Type Windings" (Paper No. 2018 S)‖ *Synopses:* January 1956

23 *Thursday*

Annual Dinner (at Grosvenor House, Park Lane, W.1, at 7 for 7.30 p.m.)

28 *Tuesday*

M. W. MAKOWSKI, DIPL.ING., *and* K. MOCHLINSKI, DIPL.ING. **M and S**
"An Evaluation of Two Rapid Methods of Assessing the Thermal Resistivity of Soil" (Paper 1942 M)‖
Synopsis: December 1955

MARCH

1 *Thursday*

Discussion on "Recruitment to the Engineering Profession" **O**
(The recent Report of the Advisory Council on Scientific Policy, obtainable from H.M. Stationery Office or the Secretary, price 1s. 3d., will be introduced. The film "The Inquiring Mind" will also be shown)

5 *Monday*

E. A. WATSON, O.B.E., D.SC.(ENG.), will open a discussion on "Is the Electrical Equipment of the Modern Motor Vehicle Sufficiently Reliable?"* **I**

6 *Tuesday*

Section Dinner-Dance (at the Criterion, at 7 for 7.30 p.m.) **S**

7 *Wednesday*

D. N. KEEP, B.SC.(ENG.) "Frequency-Modulation Radar for Use in the Mercantile Marine" (Paper No. 1940 R)‖ *Synopsis:* November 1955 **R**

13 *Tuesday*

J. C. WEST, PH.D., M.SC., J. L. DOUCE, PH.D., *and* R. K. LIVESLEY, PH.D. **M**
"The Dual-Input Describing Function and its Use in the Analysis of Non-Linear Feedback Systems" (Paper No. 1877 M)‖ *Synopsis:* July 1955

14 *Wednesday*

Education Discussion Circle visit to the Science Museum, South Kensington, at 6.15 p.m. The programme will include a talk on the Museum's Electrical Communications Collection by G. R. M. GARRATT, M.A. (Tea will be available at Savoy Place from 5.15–5.40 p.m. for members wishing to meet there before travelling to South Kensington by public transport) **E**

15 *Thursday*

C. D. J. STATHAM, B.ENG., PH.D. **U**
"Underground Lighting in Coal-Mines" (Paper No. 2034 U)§ *Synopsis:* See page 121

16 *Friday*

Radio and Measurement Sections Dinner-Dance (at the Café Royal, at 7 for 7.30 p.m.) **R and M**

19 *Monday*

Informal evening on "Electronics and Automation," at which there will be a talk (with films and demonstrations) on "Some Industrial Applications" given by H. A. THOMAS, D.SC.† **R**

21 *Wednesday*

G. F. KENNEDY, M.A. Informal Lecture on "American Power Station Practice"‡ **S**

27 *Tuesday*

E. FRANKLIN, M.SC.(ENG.), PH.D., *and* J. B. JAMES **M and R**
"The Application of Transistors to the Trigger Ratemeter and Power Supply Circuits of Radiation Monitors" (Paper No. 2049 M)§ *Synopsis:* See page 121
And other associated papers.

District Meetings

Arrangements for District Meetings other than those in the area of a Local Centre.

MAIDSTONE (At the Prince of Wales Hotel, Railway Street, Chatham, at 7 p.m. Tea at 6.30 p.m.)

March **6** *Tuesday* CAPT. F. J. WYLIE, R.N.(RETD.) Informal Lecture on "Radio Aids to Marine Navigation"

HATFIELD (At the Hatfield Technical College at 7 p.m. Tea at 6 p.m.)

March **20** *Tuesday* E. C. CHERRY, D.SC. "Information Theory"*

* No advance information will be available.
† An abstract of the introduction will be available in advance.
‡ A synopsis will be available in advance.
§ This paper will be published not later than 10 days before the date of reading.
‖ This paper has now been published separately (see p. 120)

District Meetings (*contd.*)

OXFORD (At the Southern Electricity Board, 37 George Street, Oxford, at 7 p.m.)

March 14 *Wednesday* W. OWEN ROBERTS. "New Tools in Industry—Ultrasonics."*

READING (At the George V Room, George Hotel, King Street, Reading, at 7.15 p.m.)

March 19 *Monday* B. L. GOODLET, O.B.E., M.A. "The Nuclear Power Programme."*

* No advance information will be available.

British Nuclear Energy Conference

MARCH

20 *Tuesday* A meeting sponsored by The Institution of Chemical Engineers will be held at the Royal Institution, Albemarle Street, W.1, at 5.30 p.m. (Tea at 5 p.m.) No tickets of admission are required.

C. M. NICHOLLS, B.SC.(ENG.), J. B. MORRIS, PH.D., *and* F. W. FENNING, B.A.
"The Application of Fluidization Techniques to Nuclear Reactors"*

28 *Wednesday* A Symposium on Nuclear Energy will be held at The Institution of Mechanical Engineers, 1 Birdcage Walk, S.W.1, at 3.00 p.m. Admission will be by ticket only, obtainable from the Secretary of The Institution of Mechanical Engineers. The titles of the papers to be read and discussed are given below. It is hoped to include details of the authors' names and synopses of the papers next month. Applications for advance copies of the papers should be addressed to the Secretary of The Institution of Mechanical Engineers and should be accompanied by a stamped addressed envelope (preferably 9 in. × 6 in.).

"Nuclear Reactors for Power Generation"
"Steam Cycles and Nuclear Power Plant"
"Heat Removal from Nuclear Power Reactors"
"Shielding Against Nuclear Radiation"

* For synopsis see p. 122.

Contents of the Current Issues of the Proceedings

DATE OF JOURNAL REVIEW OR SPECIAL ARTICLE

PART A. POWER ENGINEERING (FEBRUARY 1956)

SIR GEORGE H. NELSON, BART.
December 1955 **Inaugural Address**

L. DRUCQUER
February 1956 **Supply Section: Chairman's Address**

D. B. HOGG, M.B.E., T.D.
February 1956 **Utilization Section: Chairman's Address**

Local Centre, Sub-Centre and Group Chairmen's Addresses

Written discussion on **A Short Modern Review of Fundamental Electromagnetic Theory**

PROFESSOR F. BRAILSFORD, PH.D., B.SC.(ENG.)
Ferromagnetism in Relation to Engineering Magnetic Materials (*A Review of Progress*) (PAPER NO. 1947)

Not yet reviewed L. L. ALSTON, PH.D., B.SC.(ENG.) **A Voltage Divider containing a Non-Linear Unit** (PAPER NO. 1945 M)

February 1956 J. RAWCLIFFE, M.SC.TECH. **A Note on the Theory of Oscillating-Electrode Voltmeters** (PAPER NO. 1966 M)

January 1956 E. HOWARD COHEN, PH.D. **The Electric Strength of Highly Compressed Gases** (PAPER NO. 1922 M)

Discussion on **The Electrification of the Manchester–Sheffield–Wath Lines, Eastern and London Midland Regions, British Railways** before a joint meeting of the Liverpool Engineering Society and the Mersey and North Wales Centre, the North-Eastern Centre and the South-East Scotland Sub-Centre.

Discussion on **Some Design Features of the Semi-Outdoor Power Station at Ince** before the Southern Centre, the Mersey and North Wales Centre, the North-Eastern Centre, the North-Western Supply Group, the South Midland Supply and Utilization Group, the Western Supply Group, the North Midland Centre and the South-East Scotland Sub-Centre

Discussion on **The Co-ordination of Insulation of High-Voltage Electrical Installations** before the North Midland Centre

Written discussion on **Distortion of Turbo-Alternator Rotor Windings through Thermal Stress**

PART B. RADIO AND ELECTRONIC ENGINEERING (JANUARY 1956)

See *Journal*, January 1956, page 82.

PART C. MONOGRAPHS (SEPTEMBER 1955)

See *Journal*, September 1955, page 620.